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FINAL REPORT

on

REVIEW OF PRICING POLICY ALTERNATIVES FOR THE OPERATIONAL LANDSAT SYSTEM

(Report No. BCL-OA-TFR-77-6)

by

R. W. Earhart, J. A. Madigan,
W. F. Moore, and R. F. Porter

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FOREWORD

The study reported herein was carried out by Battelle's Columbus Laboratories for the NASA Office of Applications, as a task under Contract No. NASw-2800. The work was done under the general supervision of Dr. A. C. Robinson, Battelle's manager for the contract. Task monitor in the Office of Space and Terrestrial Applications was Mr. A. Donald Goedeke, Code EK.

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INTRODUCTION

Since the late 1960's, the National Aeronautics and Space Administration has sponsored an experimental Earth observations program. One of the goals of this program has been to transfer the technology developed by NASA to other sectors of the economy and/or government as part of the larger goal of providing as broad an access to space and space technology as possible. The Landsat Earth observation satellite program, being developed under the NASA Directorate of Space and Terrestrial Applications, has reached the point where its capabilities are useful in a broad spectrum of governmental and commercial applications. As the Landsat system evolves into fully operational status, an equitable pricing policy for all classes of data users will have to be established, according to goals set for the Landsat program. The pricing policy must be consistent with Federal guidelines and precedents and, at the same time, should encourage maximum benefit from the Landsat system and efficient uses of resources.

Accordingly, NASA's Directorate of Space and Terrestrial Applications asked Battelle to provide information pertinent to the definition of an operational Landsat pricing policy. The study documented in this report is intended to fulfill that request. Specifically, several pricing policy options have been considered and the implications of these policies have been estimated, both from the standpoint of potential market volume and the fiscal requirements placed upon the system operator.

Since the market for Landsat products will vary as a function of use, cost, and quality of data, classical market elasticity techniques for predicting future market trends are uncertain. In recognition of this uncertainty and its impact on the fiscal requirements for the

system operator, specific recommendations for further study have been identified.

The recommendation of a particular pricing policy is beyond the scope of this study. Instead, several alternative policies are examined and existing precedents within the Federal Government are identified. The alternative policies are characterized by the extent to which the costs of system operation are recovered.

SUMMARY

This study was conducted to examine a range of pricing policy options for the operational Landsat system and to provide recommendations for further studies to support a final selection of an operational LANDSAT pricing policy.

A parametric examination of pricing policy options considered the precedents within the Federal Government for various policies which might be adopted, and the fiscal implications of various pricing options from the standpoint of the system operator.

The candidate pricing policy options were characterized by the portion of total system costs to be recovered from the users. The generic options considered were:

(1) Full cost recovery

(2) Operational system cost recovery

(3) Direct average cost recovery

(4) Direct user cost recovery.

The major steps in this study were a market demand analysis to determine the expected volume of the future data requirements of users, and a price sensitivity analysis to examine the effect of price on market volume. From these, an estimate was made of the annual recovery required for system operation for each pricing policy alternative.

Deficiencies in the current state of knowledge were noted in such key areas as the future volume and product mix (tapes vs photos), and the elasticity phenomenon which will govern the price/volume relationships. Specific recommendations for further study are suggested to provide more complete data for a comprehensive pricing policy analysis.

With currently available information, the analysis concludes that it may be difficult to attain the business volume required to support cost recovery greater than direct user costs. Pricing policies designed to recover a higher level of system costs should be supported by further studies to demonstrate a significantly greater growth in market volume than is indicated by current analysis of demand for Landsat products. It is noted that current projections of future benefits from an operational Landsat system may support a public interest approach to Landsat pricing.

DISCUSSION OF RESULTS

Market Analysis - Potential Demand

An operational market demand for Landsat data was developed by constructing data-use scenarios for several major applications. The scenarios were derived primarily from existing studies which examined Landsat applications and associated benefits. The complete analysis of market demand is presented as Appendix A, together with a price elasticity analysis of both imagery and computer-compatible tapes (CCT). Requirements by user sector, based on the scenarios of Appendix A are:

User Sector	Scenes/Year
Private	39,796
Foreign Governments	10,076
U.S. Government	9,868
Academic	4,798
State Governments	816
Total	65,354

Converting scenes per year to frames of imagery required results in about 220,000 frames required annually. The mix of products in an operational system is projected as:

Sector	Scenes/Year Imagery	Scenes/Year CCT	Equivalent Total Frames
Private	26,497	13,299	132,687
Foreign	3,978	6,098	36,326
U.S. Government	3,873	5,995	35,599
Academic	3,838	960	15,354
State Government	545	271	2,719
Total	38,731	26,623	222,685

Because of the sensitivity of revenue projections to product mix (computer products vs imagery), a parametric treatment of the effect of product mix on revenues is presented later in the discussion of cost recovery. Both a highly CCT-oriented mix and a highly image-oriented mix are considered as well as the mix projected above.

One conclusion drawn from the analysis is the requirement to increase the utilization of computer products in order to increase Landsat system revenues. About 26,000 computer-compatible scenes will be required annually in an operational mode, with about 15,000 of these in agricultural applications. The current market for computer-compatible tapes is about 2,000 tapes annually. The increase in computer-compatible tape usage will account for the majority of the revenues from an operational system.

A comparison to existing market demand can be made by converting demand to equivalent frames of imagery (e.g., a CCT has an equivalent of 4 frames of imagery, a color image has 3 frames). This comparison is shown below:

Sector	Projected Frames		Fiscal Year 1976 Frames	
	Quantity	Percent by Sector	Quantity	Percent by Sector
Private	132,687	59.6	61,361	24.0
Foreign	36,326	16.3	66,474	26.0
U.S. Government	35,599	16.0	97,154	38.0
Academic	15,354	6.9	28,123	11.0
State Governments	2,719	1.2	2,557	1.0
Total	222,685	100.0	255,669	100.0

It should be noted that 56 percent of the U.S. Government purchases during FY 1976 were in support of NASA Principal Investigators (PI's), inflating the U.S. Government share. The 38 percent shown for the Federal sector is distributed as follows: NASA PI, 21.3 percent; USGS, 11.8 percent; and other Federal agencies, 4.9 percent. It should also be pointed out that reliability of current market data by sector directly impacts comparison between future projections by sector and current demand. The need for more refined market information than is currently available is discussed below.

Need for Better Understanding of Market Dynamics

The potential market demand for operational Landsat data was derived primarily from existing studies which examined Landsat applications and associated benefits. These included such sources of future applications as:

"United States Benefits of Improved Wheat Crop Information From a Landsat System", ECON, Incorporated, 1976

"Practical Applications of Space Systems", National Research Council, 1975

"An Analysis of Costs and Benefits From Use of ERS Data in State Land Use Plannaing", Earth Satellite Corporation and Booze-Allen, 1974

"Resource Sensing From Space, Prospects for Developing Countries", National Research Council, 1977

"A Cost-Benefit Evaluation of the Landsat Follow-On Operational System", Goddard Space Flight Center, 1977

Studies of current Landsat applications were utilized as well, for example:

"A Summary of the Users Perspective of Landsat-D and Reference Document of Landsat Users", NASA, 1977

"Survey of Users of Earth Resources Remote Sensing Data", Battelle, 1976.

Despite the many studies performed recently, a major deficiency in the existing literature is a lack of a clear transitional relationship between current Landsat applications and data users, and future market potential. The studies of current users, for example, point out key problem areas and user needs critical to market development, but they do not consider the development of new technology, nor do they quantify the potential market demand which would come about if the market and technology were properly developed. The studies of future markets, on the other hand, assume that a certain level of Landsat utilization will be required for a given application, and consider the benefits and costs associated with that application. These studies, however, do not address the issue of how the market should be developed for the applications, or what the logical transition from current to future applications will be.

In addition to the lack of information on the logical transition of current market demand into future demand, and the quantitative impact of supplying technology to satisfy specific user requirements to encourage new applications, quantitative information on current applications is not maintained. The existing user information system at the EROS Data Center, for example, provides the following type of information:

Information by User Category

	FY 1976 Landsat	
	Percent of Items	Percent of Dollars
Federal	38	35
Foreign	26	25
Industry	17	18
Academic	11	10
Individuals	7	11
State & Local	1	1

As shown, information is available by user category; however, no information is kept by application, e.g., exploration, land use planning, etc. Further, the existing information system had inherent deficiencies which could lead to misclassification of users, particularly non-government users. An example of difficulty with the existing user category system is the

university professor who purchases data for an oil company as part of a consulting contract. The "end user" appears as the academic sector rather than the private sector. The extent of this sort of activity is unknown. Another example is the category "individuals". It is not known whether these are school children or consultants. In the Federal sector, it is not known, for example, how much is for research purposes and how much is utilized in an "operational" mode. The situation makes market analysis difficult.

In 1974, EROS did attempt to operate a system to keep track of data use by application and user category, but it became cumbersome and time consuming. The breakouts were delineated by department, by agency, and by type of industry, for example, in addition to application area.

Two key issues led EROS to abandon efforts to keep finely delineated data on applications and users. They indicated that:

(1) Precise data were impossible to obtain because some users did not want to reveal their applications

(2) Collection of data borders on violation of privacy acts.

It has been estimated by EROS that, to properly generate the data required for application and user category analysis, an expenditure in excess of $100,000 per year would be required.* A trained person who understood various end-data applications would probably have to contact each person ordering data. There are about 3500 to 4000 inquires per month at the EROS Data Center which result in about 2500 orders per month, or 30,000 orders per year. Estimated costs are $3 to $5 per order to obtain the information, including personal telephone costs. Further, there is still no guarantee that precise information could be gathered, since some users would not want to discuss applications. Nonetheless, some type of data system for Landsat application areas should be implemented in order to better understand existing marketplace dynamics. This is an area that warrants further investigation.

The lack of market understanding goes deeper than the question of which sectors are purchasing what information for what applications.

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* Unless otherwise specified, all dollar values cited have been converted to 1976 dollars.

Information on user costs of using Landsat data and the economics of alternative data use, e.g., aircraft data, is sketchy. The costs of aircraft data collection ($5 to $15 per square mile) are available, but costs of data use vary considerably by application.

The interaction of the user's budgetary process and future Landsat price increases is not well understood. For example, the total cost of producing a map from Landsat data may be $30,000, of which the Landsat data tape cost portion is $200. The $200 may appear as a line item in the user's budget, but indirect labor may not be associated with the mapmaking activity as a line item. Thus, doubling the computer tape cost may appear to double the cost of the Landsat program, but actually, a $200 increase is very small compared to overall expenses of $30,000 or more for the map. From the example, it is apparent that the manner in which the user's budget is constructed to include specific cost elements as line items affects the user's reaction to price increases.

The impact of advanced Landsat technology on future market demand has apparently never been studied in depth. For example, what in terms of market demand will happen when resolution is improved to 40 meters, or even 10 meters? Will the costs of this level of imagery be more expensive due to a more complex technology, or less, because of increased market demand?

The issues discussed above impact the viability of an operational Landsat system, and deserve in-depth investigation. The basic question of the logical transition of the current market into the future in the face of user requirements and likely technological advances remains one of the most significant aspects of the Landsat program to be developed.

Pricing Landsat Data for Cost Recovery

Demand and Prices

At the present time, there are three estimates of the demand for Landsat imagery, all standardized on the nominal 100-nmi square:

- Our estimate of operational demand based on application and sector analysis: 65,354 scenes per year (Appendix A)

- The GSFC estimate of 200 multispectral scanner (MMS) and 100 thematic mapper (TM) scenes per day or 110,000 scenes per year, which is a peak rate used to size the system[(1)*]
- Market history, which indicated a peak demand in FY 1976 at 250,000 film images and 2300 tapes (Appendix A).

Estimates of future demand are based on the use of computer compatible tapes (CCTs) which are required to provide high resolution and data frequency for many applications. The current market demand for the tapes, however, is considerably less than the projected demand. If the current demand for film images is translated into the equivalent number of tapes on the basis of gross information content, the current demand is already at the projected future demand level. Market information suggests, however, that the demand for film images is highly elastic.

The market history, moreover, suggests that saturation is occurring at current prices and general capabilities of the film image data, which are usually resolution limited. The current products available are film with a resolution of approximately 100 meters costing in the range of \$7 to \$15 depending upon the type of product (B&W, color, etc.), and tapes of the same scenes costing \$200. Producing imagery from the tapes costs approximately \$2000 more, but yields resolution of approximately 40 meters. The \$2000 provides an initial press run of 100 copies and more copies can be run from the same plates at 45 cents each.[(2)] The comparable incremental cost for a film image provided by the EROS Center is approximately 25 cents. Thus, the major costs currently experienced by the serious users are in the area of processing and applying the data. While tape or other direct data products are considered to be the major growth product, there is also expected to be a significant demand for the photographic products, as they now exist. In addition to technical applications where the users will wish to check a scene for suitability for their purposes, there will be an educational, cultural and scientific demand for the coarser scale data which is probably best supplied by the unenhanced data in an inexpensive film format.

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* Superscript numbers denote references, which are at the end of the text.

Landsat System Cost Estimates

System costs have been determined from the peak demand estimate of 200 MSS and 100 TM scenes per day. The user subsystems are sized to produce the benefits determined in the GSFC benefit and cost analysis.[1] Historical information used to determine sunk costs was taken from the General Accounting Office report[3] and the GSFC analysis[1]. A stream of historical and projected costs was used to derive the annual average cost estimate presented in Table 1. The detailed cost stream-related information is presented in Appendix B. There are some differences between the costs quoted here and those in the referenced publication. The differences relate chiefly to differences in methodology rather than differences in physical costs. The GSFC analysis is directed toward estimating initial and subsequent investments and operations expenses adequate to produce a benefit stream and assumes only replacement of physically worn-out equipment. This study examines implications of many pricing policies. Some of these policies require recovery on a basis of conventional accounting techniques such as depreciation over the expected technologically useful life rather than the potential physical life. The effects of these considerations as well as the phasing of growth in demand on funding requirements are examined in Appendicies C and D.

This study is directed at determining the implications of pricing policies for the data and/or data services supplied to the public both directly and indirectly through other Government agencies. The goal, under current management directives, is to recover some or all of the system costs through user charges. A problem in recovering the total cost is that the Federal Government, through various agencies, is one of the major customers. Thus, unless these user agencies can pass on the charges for the data as part of their charges for their service, there will be no net recovery to the Government. The question of net recovery is not addressed in determining specific prices. It is implicitly assumed that the price paid for the data by a Government agency will be recovered. Another problem is that institution of a total cost recovery policy at the initial stages of the system will prevent or inhibit energence and growth of new and innovative uses of the data, as will be shown later.

TABLE 1. CATEGORIZATION OF LANDSAT ANNUAL ONGOING COSTS AND AMORTIZATION* (CONSTANT 1976 DOLLARS IN MILLIONS)

COST CATEGORIES		ANNUAL COST	CUMULATIVE ANNUAL COST RECOVERY
DIRECT USER COSTS	USER PROCESSING		
	DEPRECIATION OF EQUIPMENT	2.5	
	DATA CENTERS OPERATIONS COSTS	23.5	26.0
DIRECT ANNUAL AVERAGE COSTS	TRACKING AND DATA ACQUISITION PROCESSING		
	T&DA	1.5	
	DATA MANAGEMENT	8.2	
	CIVIL SERVICE	7.5	
	OPERATIONS COSTS - CIVIL SERVICE	0.9	
	SPACE TRANSPORTATION (1/2 STS/3 YRS)	3.3	
	REFURBISHMENT OF SPACECRAFT (30% OF INITIAL COST)	4.7	52.1
RECOVERY OF OPERATIONAL SYSTEM COSTS	ONGOING R&D IN SUPPORT OF OPERATIONS**	5.0	
	12 YEARS AMORTIZATION OF INITIAL INVESTMENT IN SPACECRAFT (LANDSAT D AND LATER)	11.5	68.6
RECOVERY OF ALL COSTS	INTEREST ON SUNK COST OF $400M @ 6%	23.9	
	20 YEAR AMORTIZATION OF SUNK COSTS (LANDSAT A, B, C)	20.0	112.5

* NASA/GSFC AND OMB INFORMATION (COST ASSUMED FIXED REGARDLESS OF VOLUME OR PRODUCT MIX)

** BCL ESTIMATE

Price, Demand and Cost Recovery

Under the assumption that the demand estimate of 65,354 scenes per year is realized in the form of computer products, cost recovery, in a gross sense, can be accomplished by charges for tapes in the range of \$397-\$1721. This represents recovery of costs ranging from direct annual costs to recovery of all costs including sunk costs and interest thereon. The charges are not extreme in relation to the current charge of \$200 for a tape or a nominal \$2000 spent on processing the tape for an enhanced image. These gross charges, however, do not consider any effect of increased price on the potential demand.

From market information to date, it appears that the market for imagery will be highly sensitive to the price charged for photographic products. The market data from 1973 to the present are shown graphically in Figure 1. Until 1975, the market had characteristics which indicated market start-up with rapidly growing volume in face of slowly rising prices. In the last two years, however, the price-demand relationship suggests that the market for images has become very sensitive to price. This could be due either to saturation as the result of user requirements being satisfied under current Landsat capabilities or to shortage of user funds available for imagery. The price-volume curve which would be achieved if the users had a fixed budget available for Landsat imagery is also indicated in Figure 1 as the constant budget line. While the information covers only two years, the price-volume relationship suggests that, collectively, the users have a constant total budget of \$1.2 million for Landsat imagery.

Market information on Landsat data tapes, as shown in Figure 2, indicates that the market for data tapes may be nearing saturation at the current capabilities offered by Landsat. The price of tape sets has remained constant at \$200 over most of the history of the program, and volume grew significantly until the last two years. The volume peaked in 1976 at about 2300 tapes, and appears to be slacking off to a rate which indicates that approximately 2000 tapes will be sold in FY 1977. While the current imagery volume approximates that which is indicated in the forecast of demand, the current demand for tapes is only 3 percent

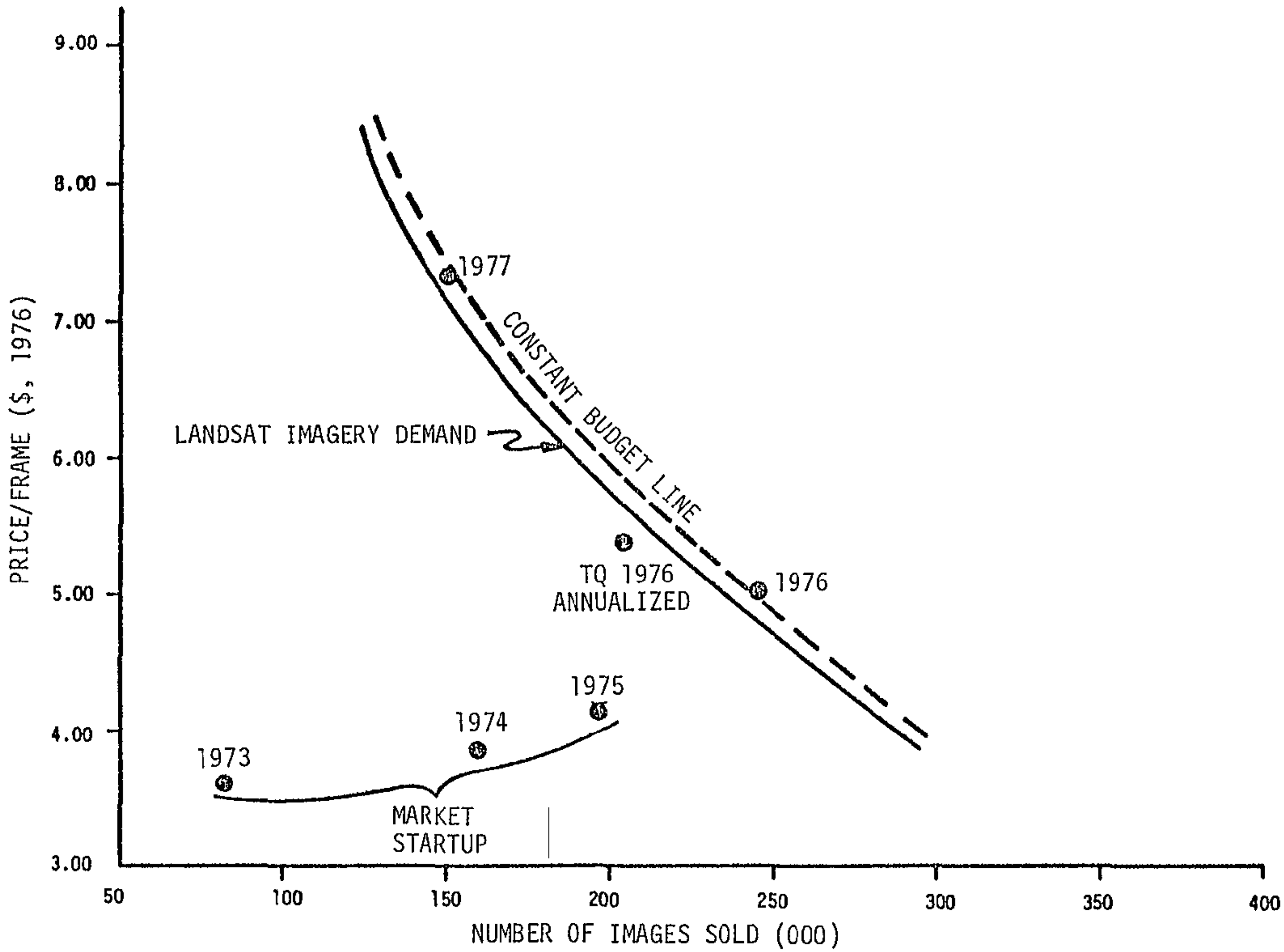

FIGURE 1. HISTORICAL DEMAND FOR LANDSAT IMAGERY VERSUS PRICE, EROS DATA CENTER

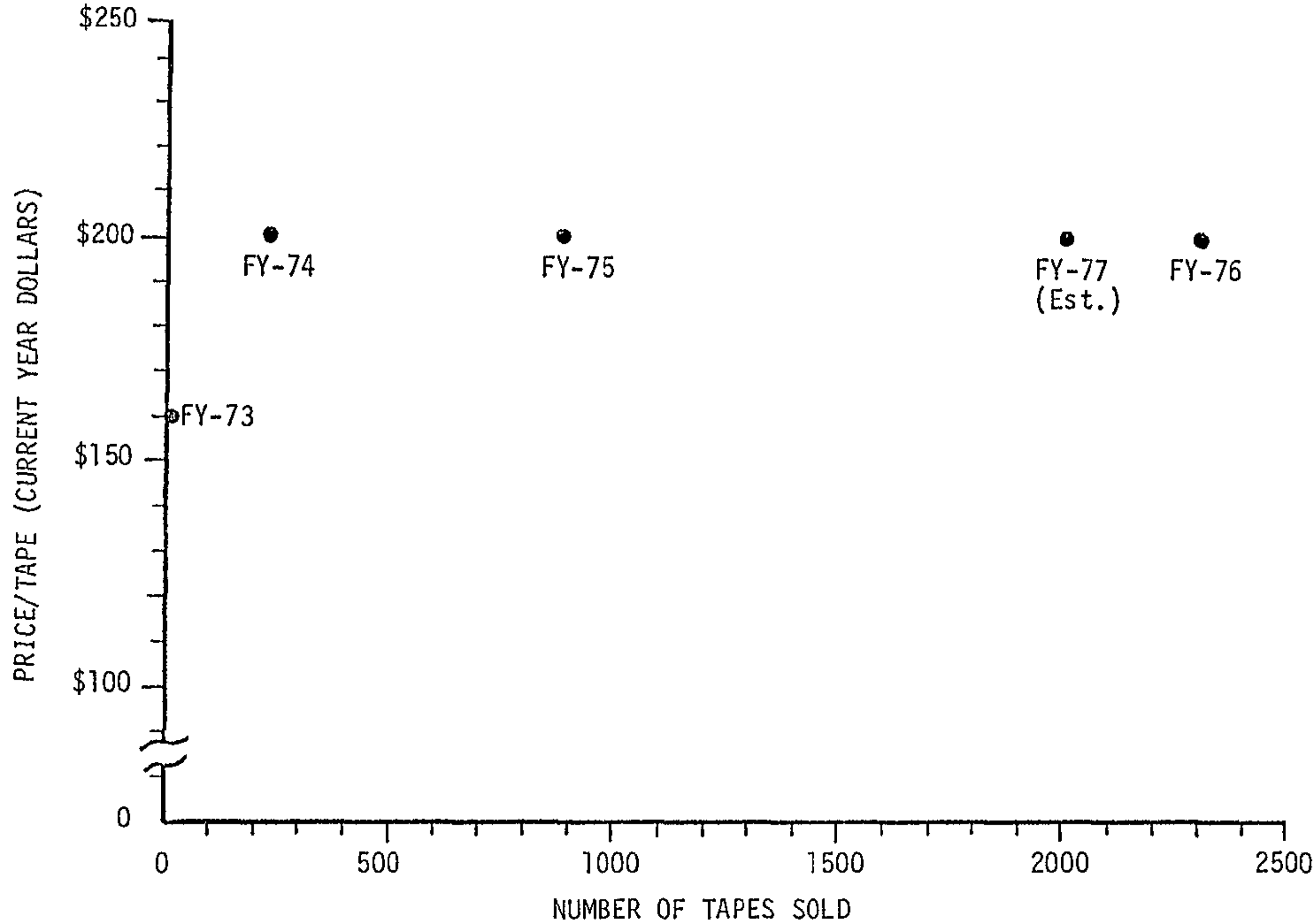

FIGURE 2. HISTORICAL DEMAND FOR LANDSAT DATA TAPES VERSUS PRICE, EROS DATA CENTER

of that which, based on projections, might be expected for an operational system, and there is no direct indication of how the demand may be affected by changes in price.

Future Unit Prices and Demand. From the hypothesis that future users of Landsat data may be on a budget, as is tentatively indicated in the data for imagery, a price-volume relationship for computer products (tapes) was derived in Appendix A. The assumption used in the derivation is that users will have a limited budget for both processing and data. A current price for commercial processing is approximately \$2000 for a 100-nmi-square scene, and the data cost \$200. This suggests that the volume may vary as the ratio of the current total price, \$2200, to the new total price for processing and data as $V = f \frac{2200}{2000 + P}$. We use $V = V_o \frac{2200}{2000 + P}$, where V_o is a parameter which adjusts for the estimate of volume at the current tape price of \$200. After limited discussions with private users, we feel that, within some nominal price range such as \$200 to \$600, demand will be insensitive to price. We have chosen \$400 as a nominal CCT price since it is in the middle of this range and will support recovery of direct user costs at the forecast of 65,354 tapes per year. The effect of this hypothetical price-volume relationship on tape demand is shown in Figure 3 for the current tape volume of 2000 per year and the forecast of 65,354 scenes per year, where that demand for scenes is expressed in a demand for tapes. The hypothetical relationship is only slightly elastic at low tape prices, $\frac{dV}{dP} \frac{P}{V} = 0.1$, where P = \$200 to \$400, but becomes more elastic at higher tape prices (- 0.7 at P = \$5000). The effect of the shift from \$200 to \$400 is also shown. While there are few market data to support the relationship, it appears reasonable in that the market would be only slightly changed at nominal price changes from the current level but would drop off significantly at very high prices. The relationship is used later to estimate cost recovery which might be achieved under various pricing policies.

In an analogous manner, a price-volume relationship for future, higher resolution Landsat imagery was determined. Based on the fact that the latest price increase at the EROS Center will result in prices in the range of \$12 to \$15 per photo for most of the products, it is likely that

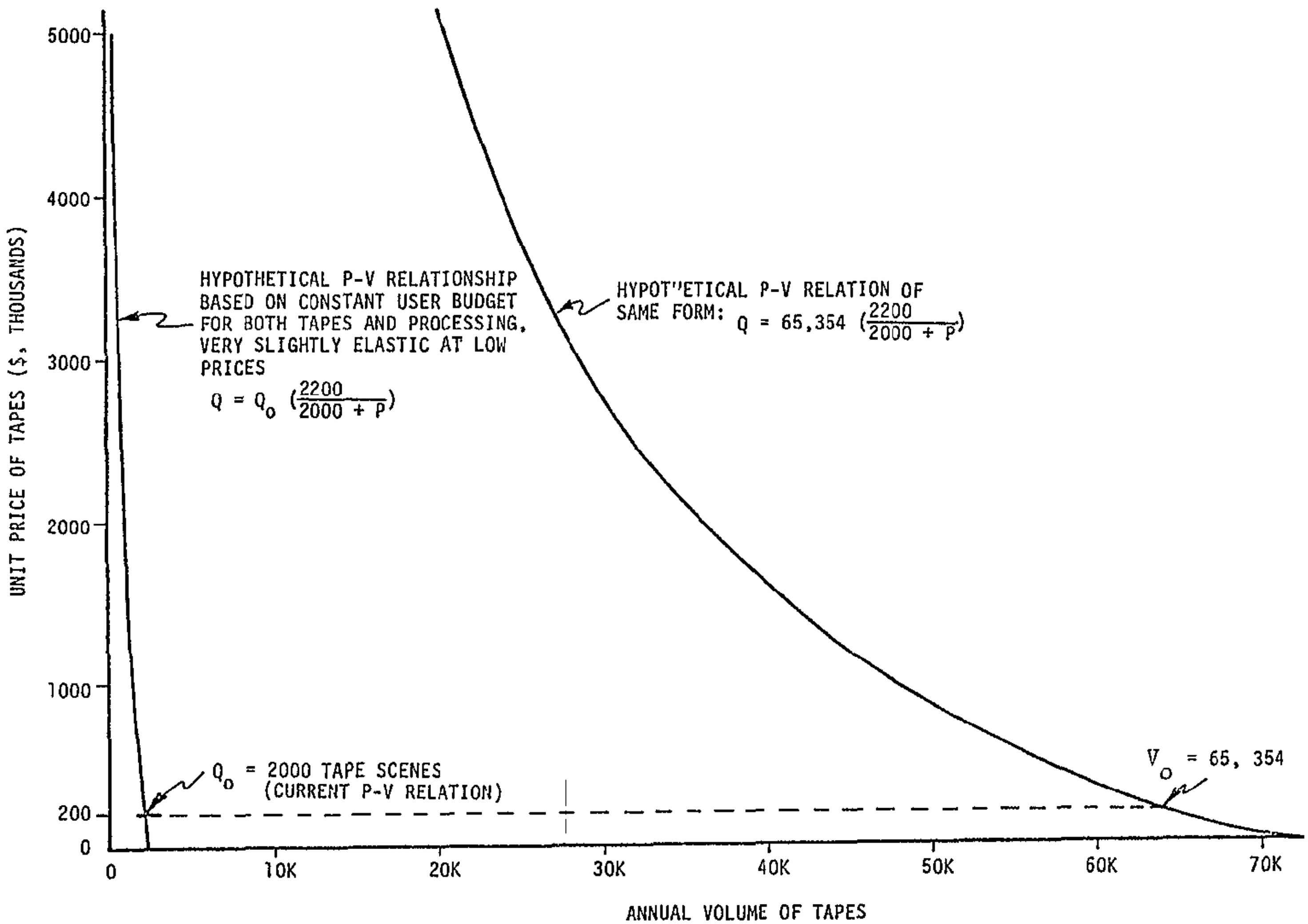

FIGURE 3. LANDSAT DATA TAPE PRICE AND VOLUME RELATIONSHIPS

new applications available with the higher quality data will enable the forecast of 222,685 film frames to be in demand at an average price of $15 per frame. If the users are then operating under a constant budget, as appears from current market information, this would imply a constant budget of $3.34 million. This price-volume relationship is indicated in Figure 4, together with an extrapolation of the current market data. The possibility that, if imagery were the only product to be offered in the future, an inelastic demand might appear is also considered in Figure 4. A possible future relationship with a constant elasticity of - 0.1 corresponding to the initial low elasticity of the hypothetical tape price-volume relationship is also indicated, as is the inelastic case.

Future Prices and Cost Recovery. As mentioned in the introduction to this section, cost recovery levels ranging from direct user costs to total cost recovery at the forecast volume of 65,354 scenes per year can be achieved from prices in the range of $397 to $1721 per scene. These levels of recovery can aslo be achieved by higher prices and lower volumes, as shown in Figure 5. The curves of Figure 5, however, show only a range of cost recovery possibilities and do not address either the product mix or the effect of increased prices on demand. In this discussion, it is assumed that the projected demand by scenes appears as a demand for tapes rather than a demand for photographs, because a cost recovery requirement of $400 per scene can be supported by tapes, but not by imagery. In Figure 6, alternative potential efforts of price elasticity on demand are shown with an itital price of $400 and an initial volume of 65, 354 scenes (tapes). Available information suggests that if the price were doubled from the current $200 to $400, there would be no significant change in demand and, at the forecasted demand of 65,354 scenes, recovery would meet direct user costs. As prices were further increased, it is likely that demand would fall off. Four potential ways in which this might occur are shown:

(1) If the users were operating on a constant budget for data purchases, it is expected that demand would follow the lowest curve and fall off rapidly as prices were increased.

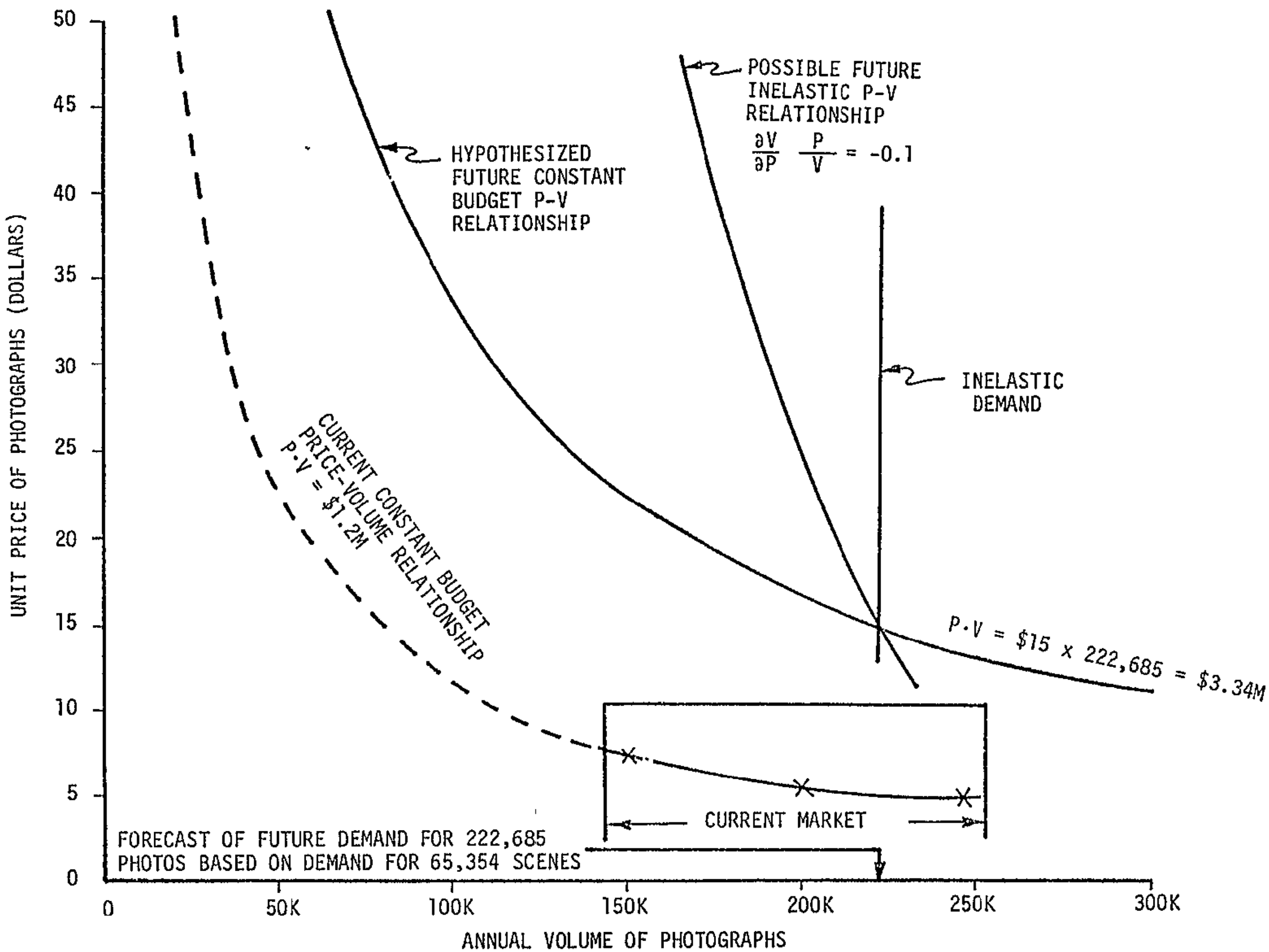

FIGURE 4. LANDSAT IMAGERY PRICE AND VOLUME RELATIONSHIP (CURRENT AND HYPOTHESIZED)

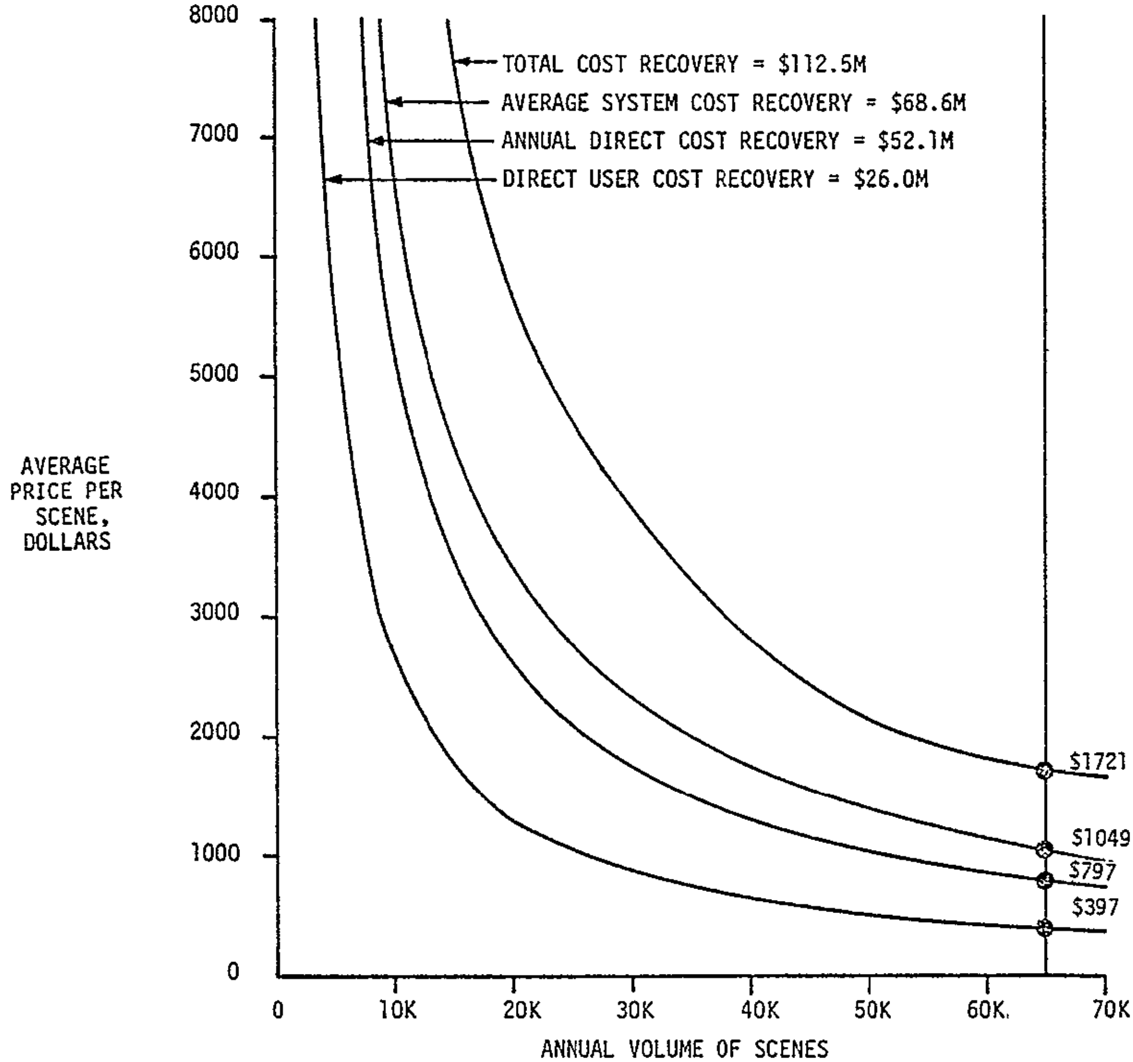

FIGURE 5. PRICES REQUIRED AT VARIOUS LEVELS OF COST RECOVERY

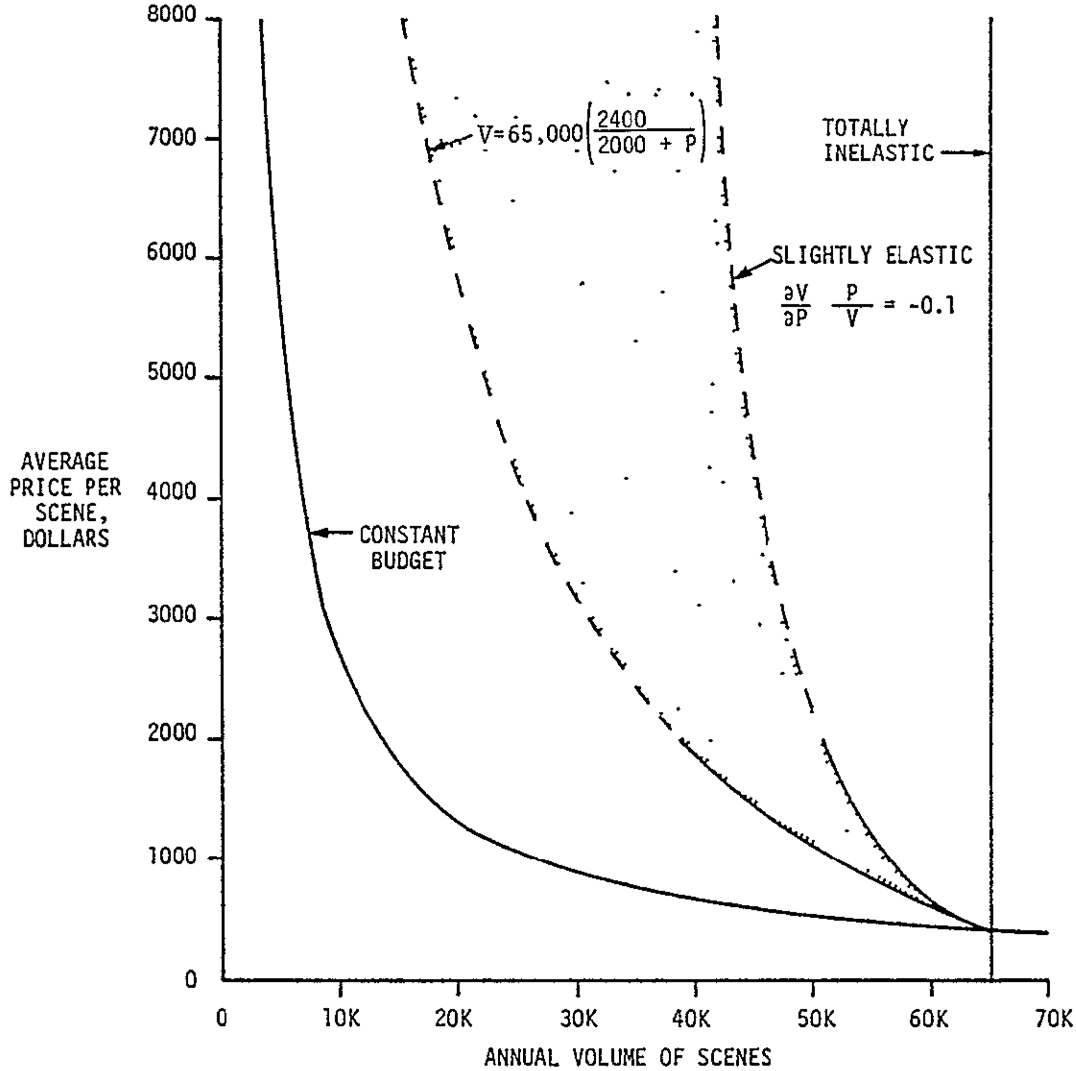

FIGURE 6. EFFECT OF PRICE ELASTICITY ON DEMAND

(2) If the users were operating on a constant budget for data plus direct costs of processing, it is expected that the demand would follow the next highest curve. Here, it is assumed that the cost

(3) If the demand were slightly elastic, such that as the price is doubled, volume would decline by 10 percent, then the price-volume relation would follow the third curve.

(4) If demand were totally inelastic, the tapes would be purchased without regard to price. This is represented by the vertical line.

If the potential demand for scenes materializes, it is expected that the price-volume relationship may be somewhere between the constant budget plus processing curve and the slightly elastic demand curve, represented in Figure 6 by the shaded region. This shift in the price-volume relation is expected because users will become locked into Landsat data usage for operational purposes, while at the present time they are still learning to use the data.

When these sets of cost recovery and price-volume relationships are combined as in Figure 7, a set of prices for recovering specified levels of costs can be found. These range from $400 for direct user costs to $5400 for the recovery of total costs under the constant budget (including enhancement) assumption. Under each cost recovery assumption, the demand that must occur at different price levels is shown. From the price sensitivity analysis, we estimate that the most probable region for the price-demand curve is the shaded region of Figure 7.

The cost-demand-price analysis, is however, a solution of formal equations. Demand at prices significantly higher (>$1500) than those currently charged is not known and can only be surmised. If the assumed applications are developed and primary reliance is placed on tapes, it is very likely that direct user cost recovery will be feasible. If, however, recovery of more than direct user costs is desired, further knowledge and analysis of potential user operations is required. Knowledge of the user's operations and their costs and returns permits a judgment of the amount of price increase which can be tolerated. When users are directly asked about price sensitivity, the answers are usually

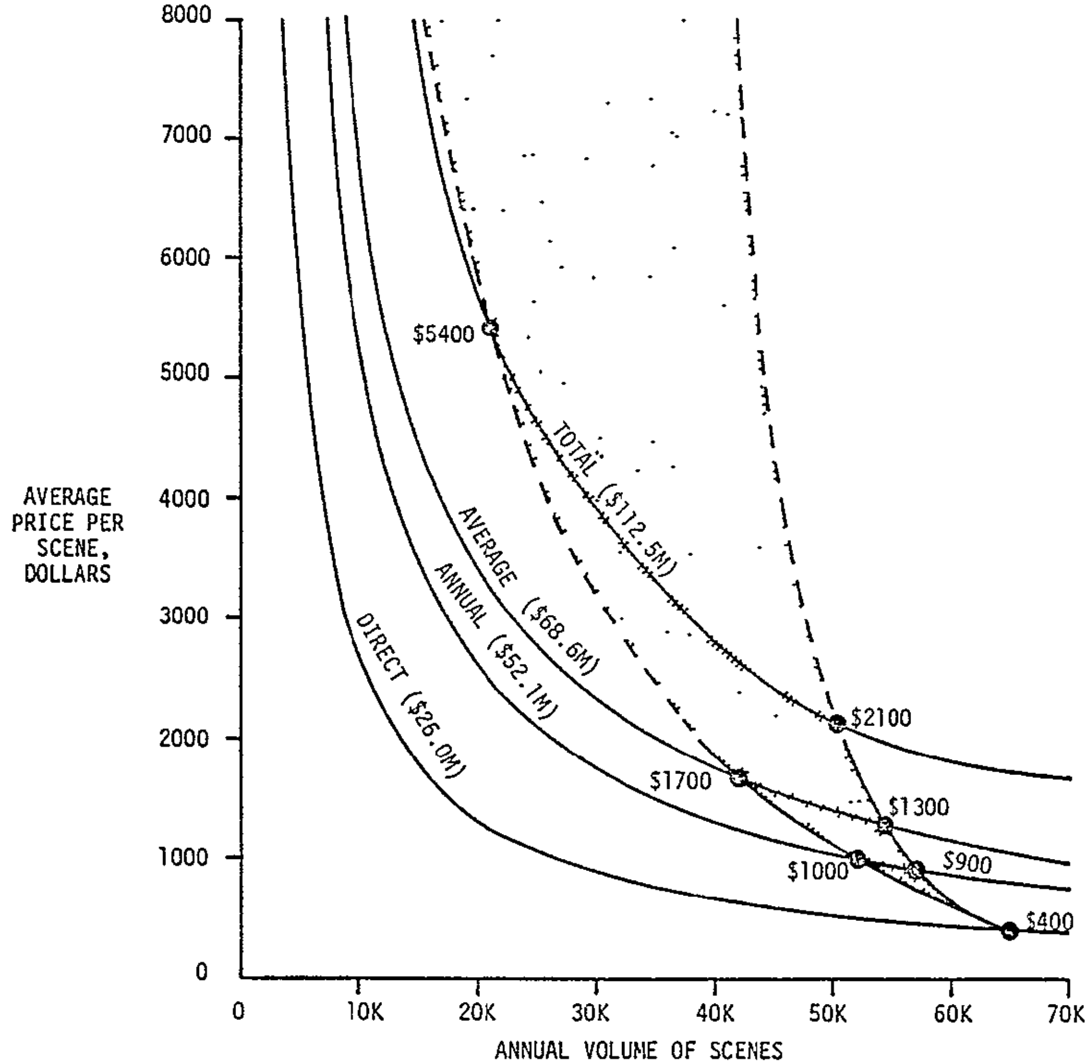

FIGURE 7. PRICES REQUIRED AT VARIOUS LEVELS OF COST RECOVERY

assertions that only minor cost increases can be absorbed without radical changes in either the structure or recovery from the operation. Analysis of the potential effects of price increases on demand is presented in Appendix C. Several alternative forecasts of the rate of growth and its effects on revenue and cost recovery for the data dissemination center are made in Appendix D.

Comparison With Aerial Photography

Landsat data prices considered range from $15 per photograph to $10,000 for a tape. The equivalent charges on a per-square-mile basis with the assumption of a 100-sq. mi. scene range from $0.0015 to $1.00 per sq. mi. Processing to a rectified, color-corrected image from tape would add $2000 to the cost basis, resulting in a nominal upper bound cost of $1.20 per sq. mi. All charges considered compare favorably with new aerial photography which costs from $5.00 per sq. mi. for high-altitude work to $14.00 per sq. mi. for low-altitude work.[4] While this cost comparison is quite favorable even at extreme charges for tapes and processing, Landsat data lack the flexibility of aerial photography and must offer either a cost advantage or a marked technical advantage to the user to capture a significant market share. Since any technical advantages are still in the early stages of development, there is some doubt that demand would develop at very high charges. A comparison of Landsat and new aerial photography is presented in Figure 8, which illustrates trade-offs at various levels of Landsat data tape charges under the assumption that Landsat data and aerial photos are equally acceptable to the user with respect to technical parameters such as spectral bands and especially resolution. At high tape charges (greater than $2000), both low- and high-altitude photography are still competitive for moderately sized areas such as a county (20 x 40 mi. = 800 sq. mi.), and would still be attractive to users with interest in a specific metropolitan area or even for small-scale regional planning.

Price Analysis Conclusions

The major analytical, as opposed to policy, conclusion drawn from this analysis is that, whatever pricing policy is selected, it should encourage use of data tapes and outside processing over photographic products. Current market information suggests that the demand for tapes

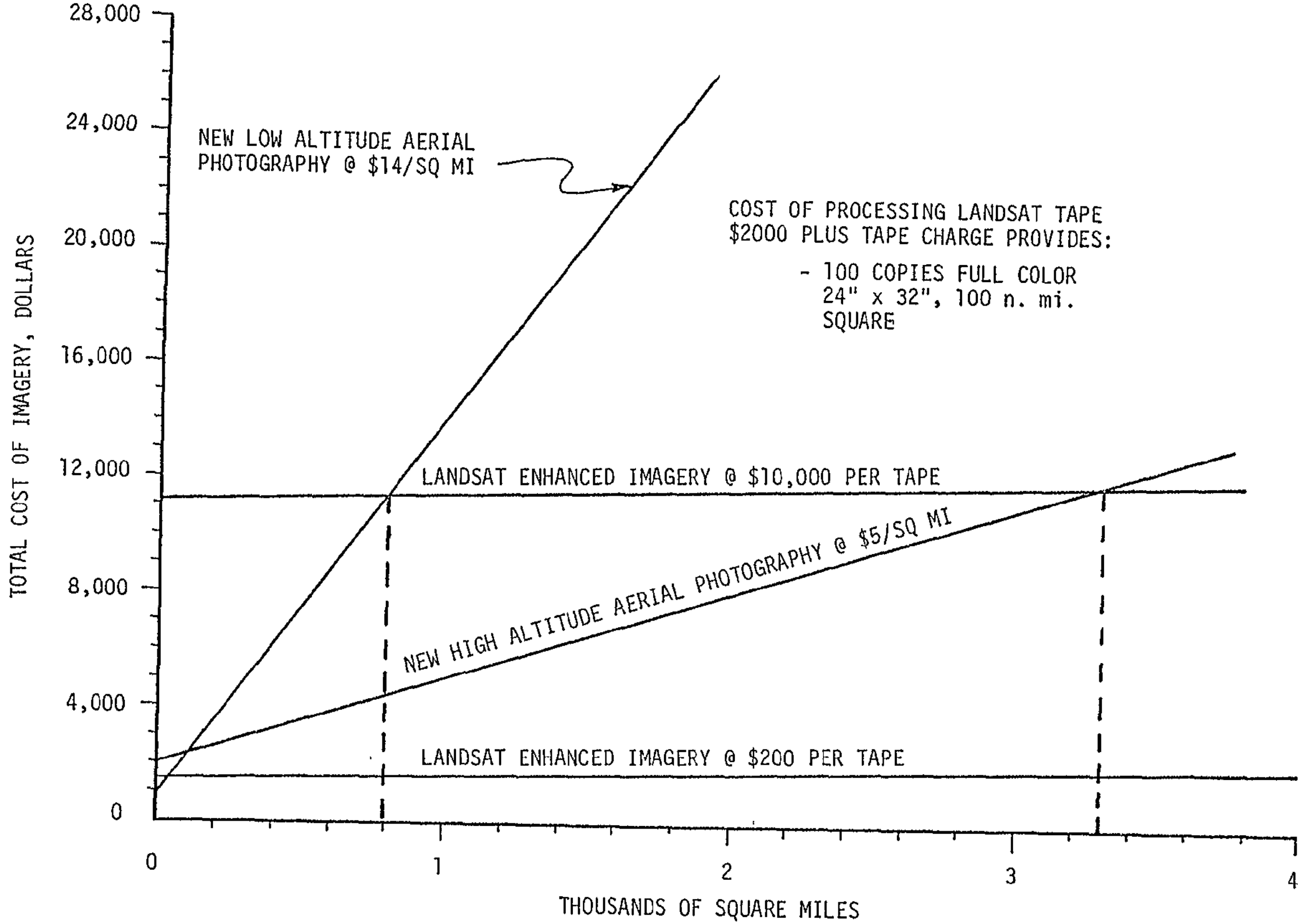

FIGURE 8. TOTAL COST COMPARISON OF AERIAL PHOTOGRAPHY AND LANDSAT IMAGERY

is not very elastic, particularly in comparison with photographic products. The current market volume for tapes is so small, however, that very high charges for tapes may tend to inhibit the development of applications which would increase the volume.

Potential Pricing Policies and Their Implications

Review of Federal Pricing Policies

Federal pricing policies(5) usually have as a goal the recovery of some or all of the costs of providing the good or service. The range of policies is indicated in Table 2. Some policies recover, or attempt to recover, more than commercial operations are charging for the same service. At the other extreme are Federal information services such as the agricultural information in books and pamphlets sold through the Government Printing Office. In this case, the charge is made only for the costs of printing and distributing the information; no charge is made for the information itself, or advertising its availability. This policy is perhaps the closest to the current policy of charges for Landsat products.

TABLE 2. PRICING POLICY PRECEDENTS

- NOAA Weather Service
  - No charge
- Government Printing Office
  - Average cost of distribution
- Panama Canal
  - Total operational cost plus interest on investment
- Tennessee Valley Authority (Electricity)
  - Total cost recovery
- Government Helium Production
  - Total cost recovery
- Launch Vehicles
  - Expendable
    - Current average cost
  - STS
    - Average cost
    - Amortization of investment
    - R&D sunk cost is not recovered
    - Incentives (small payload & exceptional payload)

EARTH RESOURCES - NTIS

Another example of a charge policy for information is the weather forecasting services. For weather forecasts there is no charge whatsoever, and immediate recipients pay only their costs, if any, for communications. The reports are also broadcast over the airwaves as a public service. This free Government service is also in competition with commercial weather services which provide special-purpose forecasts. There are many other information services within the Federal Government which also provide information at no cost or only charge for the dissemination costs. Law enforcement activities, mapping and geodetic services, and the National Technical Information System (NTIS) are examples. Clearly there are precedents for charging only for dissemination costs when the Federal Government is releasing information to the public and the public has already financed the collection of that information.

When the Federal Government provides goods or services other than information, the policies tend toward recovery of either average annual costs or these costs plus amortization of the capital investment. Examples are: (1) launch vehicles, where the government recovers the pro-rata share of annual costs plus depreciation of launch facilities, and (2) the Panama Canal, where all costs, including those of the Canal Government, are recovered as well as 6 percent interest on the initial investment in the Canal. The Federal Government also has a monopoly in the recovery of helium from natural gas in Oklahoma. That monopoly was established when there was little commercial interest in helium, and the natural gas field was the only known supply of any significance in the world. A significant capital investment was made in processing and storage facilities and a pricing policy was established to recover the current costs as well as amortization of the facilities. The gas companies operating from this field later installed their own separation facilities using newer equipment and technology and are selling helium to commercial users at prices significantly below those of the Government. Because the demand is low in relation to the currently available supply and storage facilities are limited, much of the helium is not being separated from the gas before it is released to pipelines. The Federal Government and its contractors are the largest customers for the Government's helium, while commercial users are using the lower priced non-Government gas. The Government is, accordingly, not meeting its goal of cost recovery.

As has been indicated, there is such a variety of Federal pricing policies, that it is possible to find a precedent for almost any policy. Current laws and policies also require cost recovery from direct users or beneficiaries of Federal goods or services so that taxpayers do not unduly subsidize any one segment of the population. Pricing policies, however, are usually selected on the basis of optimizing one or more criteria or objectives in addition to meeting the minimum requirements of laws and directives. For governmental activities, some of these criteria are:

- Efficient use of resources
- Equitable treatment of different users
- Maximization of benefits (including intangible benefits)
- Maximization of cost recovery
- Minimization of loss.

It should be noted that minimization of loss is complementary to, but not equivalent to, maximization of recovery. If the price is raised to such a high level that demand drops off more than proportionally, recovery will be reduced and the loss will increase.

In the non-Government sector, there are also other optimization criteria such as minimizing risk of loss and maximizing profit. It should be recognized that none of these goals is absolute; for example, profit-oriented companies will frequently sacrifice immediate profits to achieve a larger market share.

Behind any decision to select a pricing policy should be recognition of the criteria to be optimized. In this report, most of the policies discussed are presented in terms of various levels of cost recovery since some level of recovery is specified in laws and directives. When considering this range of recovery policies, attention will be directed toward the effect of the specific level of recovery on the optimization criteria/objectives. In general, policies which achieve high recovery do so at the expense of other objectives such as maximization of benefits, especially intangible benefits. Further, since demand at significantly higher prices than currently charged is not well determined, establishing prices in an attempt to maximize recovery may cause a loss of sales volume sufficient to create a larger loss than might be sustained at lower prices.

Public Interest Aspects of the Landsat Program

In considering revenue recovery for the Landsat program, it is necessary to form some judgment on the degree to which the public interest is involved, as opposed to private interest. If the future seems to lie largely with the private sector, then it is reasonable to expect that the program should be transferred, at an appropriate time, to a private organization with a minimum of subsidy. If the applications lie primarily in the public domain, however, it would be reasonable to envision Government operation and funding of an operational system. In general terms, there are two principal issues raised in considering public involvement in an operational (as opposed to a research) Landsat program. First, there is the question of the degree to which Landsat will be used to carry out or to expand activities which are traditionally in the public sector. Second, there is the matter of cost/benefit relationships: Landsat may be found to be a meritorious system, but the benefits may be so diffused through the economy that it is technically difficult to charge each of the beneficiaries a fair share of the system costs. To consider the issue of public interest involvement it is necessary to examine the key applications which have been postulated for Landsat.

A very large number of uses have been suggested for Landsat data. Quantitative estimation of benefits has been carried out for what currently appear to be the major applications. The uses which have been analyzed embody the most significant economic impacts of Landsat, at least for the next few years. One set of benefit estimates is given in Table 3. There is some degree of public interest involvement in all these applications, as discussed below.

Agricultural Crop Information. There are two separate aspects to this application: the domestic benefits to the U.S., and the benefits to other nations and to international organizations. Considering the domestic questions first, it can be observed that agriculture is the area offering the largest Landsat-derived benefits to the U.S. economy. The Large Area Crop Inventory Experiment (LACIE) is the first step in R&D to determine feasibility of crop yield forecasts for wheat. As sufficient experience is gained, new sensors, techniques, and institutional arrangements

TABLE 3. MAJOR LANDSAT APPLICATIONS AND PROJECTED BENEFITS

Application	Benefit Range (millions of 1976 dollars/year)
Agricultural Crop Information	294 - 581
Geophysical Exploration	90
Land Use Planning and Monitoring	15 - 48
Hydrologic Land Use	22
Water Resources Management	13 - 41
Forestry	7
Soil Management	5 - 9

may allow for such applications as drought and plant disease monitoring, soil monitoring, crop yield forecasts worldwide for major food crops, and possibly even farm management information in areas such as crop selection, irrigation, fertilization, and insect and disease control. The R&D investment to develop applications such as these is significant, but estimates show that benefits would be orders of magnitude greater. The question of who is the direct recipient of these benefits is difficult. Certainly it is not USDA alone, or only the farming industry that reaps the benefits. They share in the benefits that indirectly, in the case of world agriculutre, affect the well-being of the entire world. It would be impossible to assign to each beneficiary a fair share of R&D, capital investment, and recovery of operating costs. Further, an attempt to recover all costs from current users would limit the technology to applications for which there were proven "markets" and "users". While uses such as cartography and geoexploration might thrive, higher risk applications would not be attempted, and uses with significant social and economic impact, such as agriculture, would never come about.

Turning to the international aspects, it seems clear that in combination, the benefits of crop forecasting to various foreign countries would be greater than those projected for the U.S. (although the U.S. forecast is significant, as indicated in Table 3). In the U.S. case, there is an efficient domestic crop forecasting system in operation already. The principal Landsat benefits come from forecasting foreign crops, and hence forecasting the prices and markets for U.S. agricultural

products. Other nations, and particularly developing nations, have relatively poor means for domestic crop forecasting, geophysical exploration, etc. Also, various organizations interested in promoting development of the emerging nations could use Landsat information to assist in their operations.

It is clear that U.S. foreign policy is intimately involved in such applications, certainly a traditional function of the Federal Government.

Geophysical Exploration. Geoexploration is one example in which Landsat technology does appear to directly benefit a specific group. There are substantial savings in exploration costs because of the ability to rapidly survey large areas for signs of potential deposits. Costly exploration activities can be limited to geographic areas which indicate high promise. This seemingly direct application, however, has diffuse benefits reaching the entire population. It is difficult to deny that increasing the likelihood of finding new oil and gas deposits would impact the economy significantly. The question of who should bear the burden of the costs associated with this benefit to the oil companies becomes difficult in the framework of the direct and indirect benefits which accrue to several sectors of the economy as well as to the oil industry itself.

Use of Landsat Data by State and Local Governments. In the past few years, state, regional and local governments have participated in experimental programs which have substantiated the tremendous potential impact of Landsat in applications such as land use planning, environment, and resource management. Conventional data to support these functions is a costly burden, and new responsibilities are continually escalating the data demand and eroding the efficiency of state and local governments to effectively address them. In satisfying these responsibilities, the state and local governments face a growing need for large amounts of varied and repetitive data, a challenge which they have expressed will be hopefully met by advancing Landsat technology. In addition to the resource activities of state government in forestry, water resources, agriculture, fish, and wildlife, increasing demands are being placed on the state in

areas such as surface mining, power plant siting, coastal zone management, critical area programs, and other land use planning. Further, no less than 17 Federal acts and programs have been identified which place data collection burdens on the state. These include, for example, the Water Pollution Control Act of 1972, the National Envirnomental Policy Act of 1969, the Forest and Rangeland Renewable Resources Planning Act of 1974, the Clean Air Act of 1970, and several others. No less than 13 similar Federal acts are currently pending which would require still more data collection and handling.

Letters of testimony from nearly every state in the Union have shown, after 4 years of various state, regional, and local government involvement in Landsat applications, that Landsat is regarded as a necessary tool to provide a cost-effective and accurate solution to increasing data collection and handling needs. Even at the present level of development, Landsat has been shown to be cost effective when compared with existing data collection techniques. Almost every state supports further development of the system to achieve resolutions which will support additional data requirements and allow more effective conduct of their responsibilities.

Within state and local governments, the application of Landsat data to more effectively discharge responsibilities ultimately leads to diffuse economic and social benefits which accrue to the entire population. It would be difficult to determine the extent of total benefits, in economic and social terms, reaching each citizen of a particular state, and sharing the cost of the system among the various states in relationship to these benefits. In a very real sense, programs such as pollution control undertaken in one state may benefit a neighboring state more than the state which was conducting the program. The algorithm for cost sharing would be impossibly complex. The nature of state use of Landsat data and the resulting diffuse and interdependent benefits strongly suggest a Federal obligation in the development and operation of a Landsat system. This becomes increasingly evident when the experimental nature of the system is considered. The benefits depend on a high level of R&D and indicate a major Federal Government responsibility in the program.

Public Interest Justification. Landsat applications fall primarily in areas which are traditionally in the public domain. A high degree of public interest is involved, and it is difficult to recover costs through a fee structure. This suggests that, if the Landsat program has economic merit (and the cost-benefit studies indicate that it does), public support may be warranted.

It appears that of the major uses for Landsat data, there is at least one which has a major private sector application: geophysical exploration. Exploration users could reasonably be expected to pay for the Landsat products they receive at a fully burdened rate. Even here, though, encouragement of exploration is very much in the national interest.

An analysis of the potential effects of price increases on demand in the context of alternative pricing policies is presented in Appendix C.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following conclusions are drawn as a result of this study:

(1) A comprehensive analysis of the impact of Landsat operational pricing policy will require more complete knowledge than currently exists regarding:

   (a) Potential usage and market demand

   (b) Expected product mix (visual imagery vs CCT)

   (c) Price elasticity relationships.

(2) The pricing policies currently in effect among the Federal agencies vary widely with regard to the portion of total cost which is recovered from users. Precedents may be found for virtually any policy from full cost recovery to free service.

(3) The Landsat operational system appears to have public service characteristics more in common with Federal information service activities [NOAA (weather) and the Government Printing Office] than

with other Federal activities providing goods and services on a cost recovery basis.

(4) Current knowledge of future market requirements and demand strongly suggest that there will not be sufficient revenue to recover direct user costs without substantial increase in CCT sales volume. If NASA wishes to justify the Landsat operational system as a Federal information facility, there are several precedents.

Recommendations

Although the recommendation of a particular pricing policy is beyond the scope of this study, the analysis indicates that the operational pricing policy should be structured, in general, to stimulate the use of computer-compatible tapes (CCTs). The CCTs have the potential of aiding the development of new applications because of the higher quality of the product, and will probably result in higher revenue generation.

To provide a firm rationale for the development of an operational Landsat pricing policy, more comprehensive information is needed in several areas to refine the current estimates of future market volume and product mix. Specifically, further studies are recommended to provide more complete information with respect to:

(1) The actual application of Landsat data by end users
(2) The total costs of using Landsat data in various applications, and the user's budget structure
(3) The compatibility of projected Landsat technology with user requirements in each application area, and alternative data sources
(4) The future price/volume relationships for computer-compatible Landsat products
(5) The pricing and user service mechanisms for building the market to a size that will support an operational system.

If NASA intends to compare the operational Landsat to other Federal public service activities, further efforts should be directed toward demonstration that the benefits of Landsat are large and diffuse, and that cost recovery from the immediate user will be difficult and will tend to inhibit broader use of the system.

If NASA wishes to pursue cost recovery policies which will recover significantly more than direct user costs, further work must be directed toward demonstration of significiantly larger volume which will be required to make the system self-supporting.

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APPENDIX A

<u>POTENTIAL MARKET DEMAND FOR AND PRICE SENSITIVITY OF LANDSAT DATA</u>

APPENDIX A

POTENTIAL MARKET DEMAND FOR AND PRICE SENSITIVITY OF LANDSAT DATA

The potential market for Landsat was developed for several major applications and end users by constructing data-use scenarios to determine future data requirements. The applications investigated included geology and mineral exploration, agriculture, state land use planning, foreign government cartography, U.S. Federal Government cartography, and an all other uses category. Information was collected from recent studies contracted for by Federal agencies, and by personal contact with various end users, data centers, equipment suppliers, and others active in the remote sensing community.

Summary of Market Requirements and Product Mix

Table A-1 summarizes the potential market requirements by user sector. Potential demands for major Landsat applications are developed individually later in this Appendix.

TABLE A-1. REQUIREMENTS BY SECTOR

Sector	Scenes/Year
Private	39,796
Foreign Governments	10,076
U.S. Government	9,868
Academic	4,798
State Government	816
	65,354

The product mix for the applications investigated will be more heavily oriented toward computer-compatible products or enhanced imagery than the current EROS Data Center mix, which is oriented toward visual images. Both visual and CCT (computer compatible tape) products

will remain significant to specific markets. The CCT scene is derived directly from the high-density Landsat source data tape, and represents a significantly higher quality level than the visual imagery reconstructed from the source data tape, made into a master, then recopied. Because of the much higher spectral quality of the CCT, a typical geological exploration use of Landsat data is to purchase black and white transparencies (which have higher specral quality than the comparable color composite) in three of the four Landsat bands, examine the transparencies for lineaments and other features, and then order CCT data of particular scenes of interest to obtain greater detail, if required.

The cost of an enhanced CCT image available through a geo-exploration consulting firm is approximately $2000* per scene. The capital investment required to produce enhanced imagery from CCTs is about $250,000, plus the support of a highly skilled staff. It is, therefore, likely that the major exploration users would invest in equipment and staff to perform CCT enhancement in house, while the smaller users would probably turn to consultants to obtain the required enhanced imagery. Both situations indicate increased use of computer data products. The EROS Data Center at Sioux Falls, South Dakota, is planning to offer enhanced imagery shortly as part of the standard product line. The product mix will, at that time, consist of visual imagery, CCT, and enhanced CCT in either visual or computer-usable format.

A 15,000 scene per year projection for agriculture use will almost certainly be computer compatible because of both the volume of data to be handled and the timeliness of data required in crop forecasting. The system envisioned in agricultural applications would utilize direct computer input to perform the required analysis of crop yield, disease, drought, and other factors automatically without visual intervention.

Cartographic applications may make use of either visual or automated data. Automated imagery, however, will achieve cost advantages in Level I and Level II applications (1:63,500 scale and smaller) because certain labor intensive cartographic applications required in developing land use maps can be automated. The projection in land use planning and cartographic application indicates a mix of automated and visual products.

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* All dollar values in this Appendix have been converted to 1976 dollars.

Other uses will grow as improved Landsat products become available (e.g., higher resolution). These applications may be based at least initially on visual imagery, but computerization is likely in some applications. Plant site location studies and environmental monitoring are examples of this category of use.

Estimates of product mix for the various user sectors are presented in Table A-2. Because of the effect of product mix on revenues, it is important to emphasize that the direction and needs of each particular market sector, the developing base of user technology, the projected advances in the Landsat operational system and data center capabilities all impact the product mix as well as the overall market size. Exhaustive treatment of these variables is outside the scope of the current study, but deserves further attention in future efforts. In order to determine effects of the product mix on revenue projections, the mix projected in Table A-2 is examined in the report as well as both extreme cases of a highly CCT-loaded mix and a highly image-loaded mix. The analysis presented in the report indicates the relative sensitivity of mix on revenue projections.

TABLE A-2. PRODUCT MIX PROJECTIONS

Sector	Scenes/Year Imagery	Scenes/Year CCT
Private	26,497	13,299
Foreign	3,978	6,098
U.S. Government	3,873	5,995
Academic	3,838	960
State Government	545	271
Total	38,731	26,623

The mix of Landsat imagery from the EROS Data Center has averaged 20 percent color products, and 80 percent black and white products. To cover a scene in three spectral bands requires one color frame, or three black and white frames. Applications such as geoexploration heavily utilize the black and white single spectral band product to obtain a

greater degree of spectral resolution than is available with the color composite, with typical purchases being three black and white frames (spectral bands) per scene. Applying this to the above market projections yields:

Imagery Type	Frames Required Annually
Color Landsat	7,746
B & W Landsat	92,954
Computer Products	26,623

In order to compare this with the existing market for Landsat products, adjustments are required. Computer products must be converted to equivalent frames (at four frames, or bands, per CCT scene), and the color products must be converted to equivalent frames (at three frames per color scene). With these adjustments, the demand in equivalent frames shown in Table A-3 can be expressed.

TABLE A-3. DEMAND PROJECTION IN EQUIVALENT FRAMES

Sector	Scenes/Year Imagery	Scenes/Year CCT	Equivalent Total Frames
Private	26,497	13,299	132,687
Foreign	3,978	6,098	36,326
U.S. Government	3,873	5,995	35,599
Academic	3,838	960	15,354
State Government	545	271	2,719
Total	38,731	26,623	222,685

The projection in Table A-3 is compared to 1976 demand in Table A-4. The computer tapes sold during FY 1976 are converted to frames at the rate of four frames per tape, as a basis of comparison.

TABLE A-4. DEMAND PROJECTION COMPARED WITH EXISTING DEMAND

Sector	Projected Frames		Fiscal Year 1976 Frames	
	Quantity	Percent by Sector	Quantity	Percent by Sector
Private	132,687	59.6	61,361	24.0
Foreign	36,326	16.3	66,474	26.0
U.S. Government	35,599	16.0	97,154	38.0
Academic	15,354	6.9	28,123	11.0
State Government	2,719	1.2	2,557	1.0
Total	222,685	100.0	255,669	100.0

One conclusion to be drawn from the analysis is that a dramatic increase in Landsat imagery sales is not indicated for the operational applications studied, but an increase in quality level of desired products should occur, resulting in increased revenues as the market converts to a more expensive product mix, as discussed in the revenue projections below.

Requirements by Application

Geology - Petroleum And Mineral Exploration

The geological exploration community has made significant use of Landsat data during the short time the data have been available, having, for example, purchased an estimated \$800,000 [(A-1)*] worth of imagery in the form of visual data and computer compatible tapes during 1976. The information is valued in the community because of the synoptic view afforded in its small-scale imagery (1:3,369,000 and 1:1,000,000) which allows the detection of certain geological features. A recent study [(A-2)] has indicated benefits to the exploration community of the order of \$91 million annually, based on cost savings in geological and geophysical exploration operations afforded by the Landsat information.

* References, denoted by superscript numbers, are at end of Appendix A.

To bound the market for geological exploration, it is reasonable to consider the land area of the Earth as an upper limit on desired area of coverage, together with the continental shelf areas of the world, considering the recent increase in offshore drilling activity. The land area is about 57.5 million square miles, and the shelf area (to a total depth of about 600 feet) is about 5 percent of the total world surface[A-3], or about 9.6 million square miles. Geologists have expressed the need for multiple views of the same area for seasonal (especially foliage variation) analysis, and sun angle variations which provide additional geological information. Assuming two seasonal coverages with two varied sun angles (or four seasons, which may also provide the varied sun angle coverage), the equivalent area to be sensed would be 67.1 million square miles x 4 exposures, or an equivalent 268.4 million square miles.

Once complete coverage of this equivalent area is obtained by a geological user, no further requirement would exist until improved coverage became available (e.g., different spectral bands, stereo views, better resolution, and so on). Assuming that a given spacecraft would last 10 years in an operational configuration, new equipment and capabilities would be added at 10-year intervals. The 268.4 million square miles would be re-imaged at 10-year intervals with the new capability. An average of 26.8 million square miles of imagery per year would be purchased by a user during the 10-year interval under this scenario. With a Landsat scene representing a nominal 100 x 100 square miles, the number of scenes purchased would be 2680 annually. An estimated eight companies[A-4], currently using Landsat data, represent potential users of this volume of information, based on the scope of their exploration operations. The total annual market for these companies is about 21,400 scenes. In addition to the major companies, an estimated 5,400 scenes would be purchased by smaller companies and exploration consultants, bringing the total market to 26,800 scenes annually.

Wheat Crop and Corn Crop Forecasting

The implementation of a worldwide crop-forecasting system has been the subject of various studies in recent years. Based on a study

released in March 1977, by Goddard Space Flight Center [A-5], the annual benefits occurring from agricultural crop information would minimally be $294 million on the basis of monitoring worldwide wheat and corn crops alone. The analysis presented below concentrates on the imagery required on an annual basis to accomplish these benefits, with resultant market projections for Landsat data.

It should be emphasized that the market projections assume the existence of a technology which is within the resolution and data frequency requirements of end users, and which has been successfully applied to crop identification, disease monitoring, yield projections, and related applications critical to the data users.

Total planted acreage of wheat and corn [A-6] worldwide (1969-1971 average) is:

Crop	Area (Millions of Hectares)
Wheat	214.4
Corn	109.5

Expressed as square miles, the total planted area is:

$$323.9 \text{ million hectares} \times .00386 \text{ mi}^2/\text{hectare} = 1{,}250{,}254 \text{ square miles} \quad .$$

This represents the area, from a worldwide consideration, that would be useful to monitor during the growing season.

The above crops have an average growing season of 5-6 months [A-7]. If Landsat imagery were obtained for each complete Landsat cycle, about once every 2 weeks, then coverage would be obtained 12 times during the growing season. The total effective square mileage to be covered equals 12 x 1.25 million square miles, or 15 million square miles annually.

Assuming an efficiency factor of 30 percent in desired area per scene to total area covered for agricultural purposes, total data requirements would be 5,000 scenes per year, based on a nominal 10,000 square mile scene. The data rate for the required system would average about 14 scenes per day, and would not exceed 28 scenes per day even if the total world average were planted simultaneously, say, for example, near the end of the northern hemisphere growing season, and the beginning

of the southern hemisphere growing season. This is within the bounds of the system required to deliver the benefits described in the Goddard study, which was sized to accommodate 80 scenes per day.

Considering the market for agricultural imagery, one complete set would be acquired by USDA, and one set would probably be acquired by the various countries of the world in combination (each country purchasing data on at least its own agricultural conditions). It is apparent that, with substantial monies tied up in the commodity markets, at least one other full set would likely be purchased by the private sector to provide proprietary forecasted commodity information. Overall, the market for Landsat frames in agricultural use is on the order of 3 x 5000 scenes, or 15,000 scenes per year.

State Governments - Land Use Planning

A 1974 study performed under contract to the U.S. Geological Survey projected aerial data acquisition by state governments at 3.4 million square miles per year during the period 1977-1986.[A-8] The projection is based on a mix of spacecraft and aircraft data to fill state land use planning data requirements.

State data requirements for land use planning can be grouped into three scale ranges; coarse (1:500,000 scale), moderate (1:125,000 scale), and fine (1:24,000 scale). The most compatible scales for spacecraft data products are coarse and moderate, with fine-scale data needs satisfied by aircraft surveys. Some overlap of spacecraft and aircraft data acquisition will occur both in utilization of spacecraft to obtain a broad perspective of which parts are re-acquired with larger scale aircraft imagery, and in the utilization of aircraft data to provide truthing for the spacecraft imagery.

Different states have varying mixes of data requirements on the basis of percent of data acquired in coarse, moderate, and fine scale[A-9]. Further analysis of the U.S. Geological Survey study results shows the 3.4 million square mile data acquisition projection to be divided into 1.6 million square miles (47 percent) of fine scale imagery, and 1.8 million square miles (53 percent) of moderate and coarse scale imagery annually. Landsat data would be acquired primarily to meet coarse , and

with some aircraft assistance, moderate scale requirements. The fine scale imagery would be flown primarily by aircraft at an altitude of 12,000 feet. Projecting the 1.8 million square miles as primarily spacecraft compatible, the market for Landsat data is 180 scenes annually, each scene covering a nominal 100 x 100 mile area. Assuming a 50 percent efficiency in area per scene to desired area of coverage, the state government Landsat requirement is 360 scenes annually for the period 1977 through 1986.

The unit cost of data acquisition depends on the scale of the imagery. Three categories of data have the following costs per square mile:(A-10)*

Scale	Aircraft Data	Landsat Imagery	Landsat CCT
1:24,000	14.65	--	--
1:125,000	5.27	1.62	1.72
1:500,000	4.94	0.30	0.79

The costs include all operations from data acquisition through development of a usable product from the raw data. In the case of aircraft data, standard cartographic operations are included. In the case of Landsat computer-compatible tape data, fieldwork, data acquisition, reformat, computer rectification, and classification are included as well as cartography. The data in the tabulation presented above, therefore, represent the complete cost of generating the end product, and provide a basis for comparing various products. Since the current study addresses primarily the market for Landsat products, and resultant price sensitivity, it is useful to examine the Landsat data component of the above costs of data acquisition. These costs are shown below(A-11)*:

Scale	Information Cost/Mi^2	Data Type	Landsat Data Cost/Mi^2	Data Cost/ Information Cost (Percent)
1:250,000	$1.622	Imagery	$0.001	0.1
1:500,000	$0.298	Imagery	$0.001	0.3
1:250,000	$1.72	CCT	$0.02	1.2
1:500,000	$0.79	CCT	$0.02	2.5

* Cost data from References (A-10) and (A-11) are assumed to be in 1974 dollars.

These data refer to developing products which are equivalent to Anderson (1972) Level I and Level II products, for application in state land use planning. The data provide a guideline for price sensitivity of the Landsat data cost to total information acquisition cost. As an example, in the case of a 1:500,000 CCT product, the data cost is 2.5 percent of the Anderson Level I product cost. Therefore, if the Landsat CCT price were to be increased 100 percent, the overall product cost would be increased 2.5 percent. In the discussion on price sensitivity, below, this relationship is applied to develop elasticity considerations.

Foreign Governments - Cartography

In 1974, annual expenditures worldwide on surveying and mapping were $4.2 billion or about 0.1 percent of world GNP.(A-12) Excluding the U.S., world national cartogrpahic agencies spent about $243 million on base maps, including aerial photography and geodetic extension.(A-13) Expenditures were distributed by region as follows:

Region	Expenditure (Thousands of 1976 Dollars)
Africa	$ 12,123
North America (Excluding U.S.)	33,412*
South America	11,952
Europe	140,933
Asia	6,860
Oceania	37,779
Total Foreign	$243,059

Primary data acquisition is estimated to be 15 percent of these expenditures, or approximately $36.5 million. In the U.S., primary data acquisition was an estimated $10 million of which about $5.7 million was spent on aerial photography.(A-14) Applying this ratio to the foreign sector yields expenditures on aerial photography of approximately $20.8 million.

* U.S. expenditures estimated at $67 million.

Of the covered area, approximately 58 percent [A-15] was mapped at scales smaller than 1:50,000. Assuming that imagery of future Landsat systems can attain resolutions suitable for small-scale mapping (e.g., an improvement to 1:100,000 over the current 1:1,000,000), this would represent the maximum share of the aerial photography market available to Landsat. Thus, the small-scale foreign market available to Landsat scales of 1:50,000 and smaller is about 58 percent of the expenditures on aerial photography, or about $12.1 million per year.

In 1970, the annual rate of aerial photography coverage was 4.4 percent, while the rate of new or updated mapping during the period 1968-1974 grew at an annual rate of 1.3 percent. [A-16] Mapmaking activity is not currently data-input limited, but is limited by geodesy, cartography, reproduction, and other related activities. With this, it appears unlikely that the market for primary data such as aerial photography will increase significantly unless the rate of mapmaking activity, a function of economic development and population growth, increases considerably.

Exclusive of the United States, the world land mass covers about 54 million square miles. [A-17] With a data acquisition rate of the current annual 4.4 percent, about 2.4 million square miles are covered each year. A nominal 100 x 100-mile Landsat scene covers 10,000 square miles. Assuming an efficiency of 50 percent in area covered by a given scene to desired viewing area, the total foreign market for mapping activities would be approximately 480 scenes per year. It is recognized, however, that 42 percent of the mapmaking activity is directed at scales larger than 1:50,000. Assuming that resolutions are developed which will allow Landsat to be used in cartogrpahic activities involving scales of 1:50,000 and smaller, Landsat could compete for about 58 percent of the market, or about 278 scenes per year. It is unlikely that ERTS data will ever replace aircraft data in applications larger than 1:50,000 scale.

U.S. Federal Government - Cartography

In 1972, Federal agencies spent $5.7 million on aerial photography to support mapping and interpretation of about 600,000

square miles.(A-18) The expenditures do not include some $2.8 million expended by NASA to support Earth observation activities. The majority of data was obtained by the Government, under contract with private aerial survey firms, with the exception of the Corps of Engineers, the Forest Service, and the National Ocean Survey, which utilize their own aircraft.

Total Federal expenditures in 1972 on mapping, charting, and geodesy were $419 million, with an additional $196 million spent on geologic investigations related to mapping and geodesy. Expenditures for mapping, charting, and geodesy by agency are as follows:(A-19)

Agency	Expenditure (Millions of 1976 Dollars)	Percent of Total by Agency
Department of Defense	$126	30.1
Department of Interior	105	25.1
Department of Agriculture	28	6.6
Department of Commerce	63	15.0
Department of Transportation	23	5.5
Department of HUD	23	5.5
Other Agencies	51	12.2
Total	$419	100.0

Expenditures on aerial photography can be assumed to be proportional.

Almost all of the data collected were acquired at altitudes of 5,000 feet to 40,000 feet, indicating a maximum scale of 1:50,000. It should be noted that Landsat resolutions are currently generally compatible with map scales typically no larger than 1:500,000(A-20) though improved resolution of future Landsat systems is assumed for purposes of this analysis to be acceptable for the small scale (1:50,000 and smaller) portion of the market currently serviced by aerial photography. Assuming a similar pattern to world photographic coverage, the market for 1:50,000 scale and smaller is about 58 percent of the total market for all scales, indicating about a $3.3 million U.S. Federal market for Landsat products. Landsat imagery is not expected to compete in scale ranges larger than 1:50,000. To support Federal mapping and interpretation activities,

Landsat could be expected to satisfy requirements for no more than 58 percent of the current 600,000-square mile annual demand, since about 42 percent of the mapping activity requires scales larger than 1:50,000. This would indicate a total Federal Government market for cartographic applications of 348,000 square miles, or 35 Landsat scenes annually. Assuming that each scene provided 50 percent of the area required for data acquisition, the market would be about 70 scenes per year.

Other Remotely Sensed Data Applications

The markets discussed above are currently the major projected users of Landsat. There are many smaller projected uses of spacecraft data which, taken together, represent a significant Landsat market.(A-21) These uses include many additional applications in the government and private sectors.

Applications undertaken by Federal agencies include:

- Agriculture - Forest and soil classification, inventories and mapping; and forest range and grassland management
- Hydrology - Water quality; reservoir mapping and monitoring; snowfall and runoff estimates; flood damage assessments; and irrigation management
- Environmental/Ecology - Wildlife habitat; surface mining monitoring; coastal zone, and critical areas
- Oceanography - Ocean current monitoring; iceberg and sea ice monitoring; and ocean resources.

Applications in state and local governments in addition to land use planning and agriculture include:

- Strip Mine Monitoring
- Water Monitoring System and Wetland Inventories
- Other Hydrological Studies and Irrigation Studies
- Soil Association Maps
- Water Quality Monitoring
- Coast and Near-Shore Process Studies
- Ice Monitoring
- Wildlife Habitat and Rangeland Studies
- Geothermal Source Locations
- Mineral Exploration
- Tectonic Studies.

Industrial users of Landsat data, in addition to geology and agriculture, include applications in the following areas:

- Power plant sitings
- Timber monitoring
- Land use inventories
- Construction activities, such as soil mapping.

Foreign governments, in addition to applications in agriculture, geology, and cartography, have indicated interest in other Landsat applications such as snow melting, grassland monitoring, coastal zone pollution monitoring, and flood damage assessment.

A recent Battelle study addressing current user markets indicated relative discipline interest of all classes of users as 65 percent in agriculture, land use, and geology, and about 35 percent in other uses.(A-22) Extrapolating this relationship to the agriculture, land use, and geology markets projected in the above discussion indicates an all-other-use market of about 22,846 scenes per year.

Requirements by Sector

The majority of the projected applications discussed above are associated with specific market sectors, as indicated in Table A-5.

TABLE A-5. ASSOCIATION OF APPLICATION WITH SPECIFIC SECTOR

Application	Scenes per Year for Indicated Sector				
	Private	Foreign Govt.	U.S. Govt.	State Govt.	Academic
Geology - Exploration	26,800	--	--	--	--
Agriculture	5,000	5,000	5,000	--	--
State Land Use Planning	--	--	--	360	--
Foreign Cartogrpahy	--	278	--	--	--
U.S. Federal Cartography	--	--	70	--	--
Total (Less "Other")	31,800	5,278	5,070	360	0

Using the Battelle survey results to allocate the all-other category to various market sectors, the following results are obtained:

Sector	Private	Foreign Govt.	U.S. Govt.	State Govt.	Academic
Total (Less Other)	31,800	5,278	5,070	360	0
Other	7,996	4,798	4,798	456	4,798
Total	39,796	10,076	9,868	816	4,798

Price Sensitivity of Landsat Data

Historical Price/Quantity of Data Sales-EROS Data Center

Review of EROS Data Center published price information for the period 1971 through 1977 indicates the following pricing history:

	Price Per Published Price Sheet				
Product	Dec. 6, 1971	May 1, 1973	Sept. 1, 1974	Aug. 1, 1975	Jan. 1, 1977
1:3,369,000 Film Positive, B&W	$2.50	$2.50	$2.00	$3.00	$8.00
1:3,369,000 Film Negative, B&W	2.50	2.50	2.00	4.00	10.00
1:1,000,000 Paper, B&W	1.75	1.75	2.00	3.00	8.00
1:1,000,000 Paper, Color	7.00	7.00	7.00	7.00	12.00
1:1,000,000 Film Positive, B&W	3.00	3.00	3.00	5.00	10.00
1:1,000,000 Film Positive, Color	7.00	10.00	12.00	12.00	15.00
1:1,000,000 Film Negative, B&W	3.00	3.00	3.00	6.00	10.00
Computer Compatible Tapes	--	160.00	200.00	200.00	200.00

The dollar volume of Landsat imagery sales at the data center during the period Fiscal 1973 through 1977 is shown in the following table together with the number of frames of imagery sold:

	Fiscal Year					
	'73	'74	'75	'76	Transition Quarter	'77 (Projected)
Landsat Imagery Frames	81,071	157,178	195,125	246,449	50,804	150,000
Dollars (Current Year)	$228,042	$528,514	$760,263	$1,237,862	$274,229	$1,161,000

Converting this to an average price per frame in 1976 constant dollars yields:

	Fiscal Year					
	'73	'74	'75	'76	Transition Quarter	'77
Average Price/Frame	\$2.81	\$3.36	\$3.89	\$5.02	\$5.39	\$7.74
Constant 1976 Dollars	\$3.62	\$3.89	\$4.12	\$5.02	\$5.39	\$7.35

The average prices indicate the effect of product mix and price in effect which historically has been about 20 percent color imagery to 80 percent black and white imagery. Average prices are useful in projecting price/volume considerations, since they represent the average price in effect of the particular mix of products sold each year, and also average product prices as a result of price sheet changes during the year.

Price Sensitivity of Imagery

Plotting constant dollar average prices against number of images sold yields the relationship shown in Figure A-1.

Generally, definite conclusions on price elasticity cannot be drawn for a product until the market has achieved a steady-state condition. The early years of Landsat data sales through 1975 do not yield representative price-demand relationships, since the market was too immature to achieve the steady-state volume indicated at the specific price levels in effect. By late 1975, it is hypothesized that the market began to gain sufficient experience with Landsat imagery to determine relative value of the products offered with respect to applications. Through 1976, demand began to equalize, and has followed the curve postulated in Figure A-1 through 1977. Supporting the theory that the data since 1976 represent an elasticity phenomenon, is the proximity to which the price/volume relationship for imagery approaches a constant budget line. To the extent that users continue to follow the particular relationship shown in Figure A-1, revenues from Landsat imagery should remain relatively stable showing little growth or decline within the price range indicated in Figure A-1. As new applications for imagery are developed, the curve should shift to the right, indicating a greater demand for products at a specific price level. Similarly, as higher quality products become

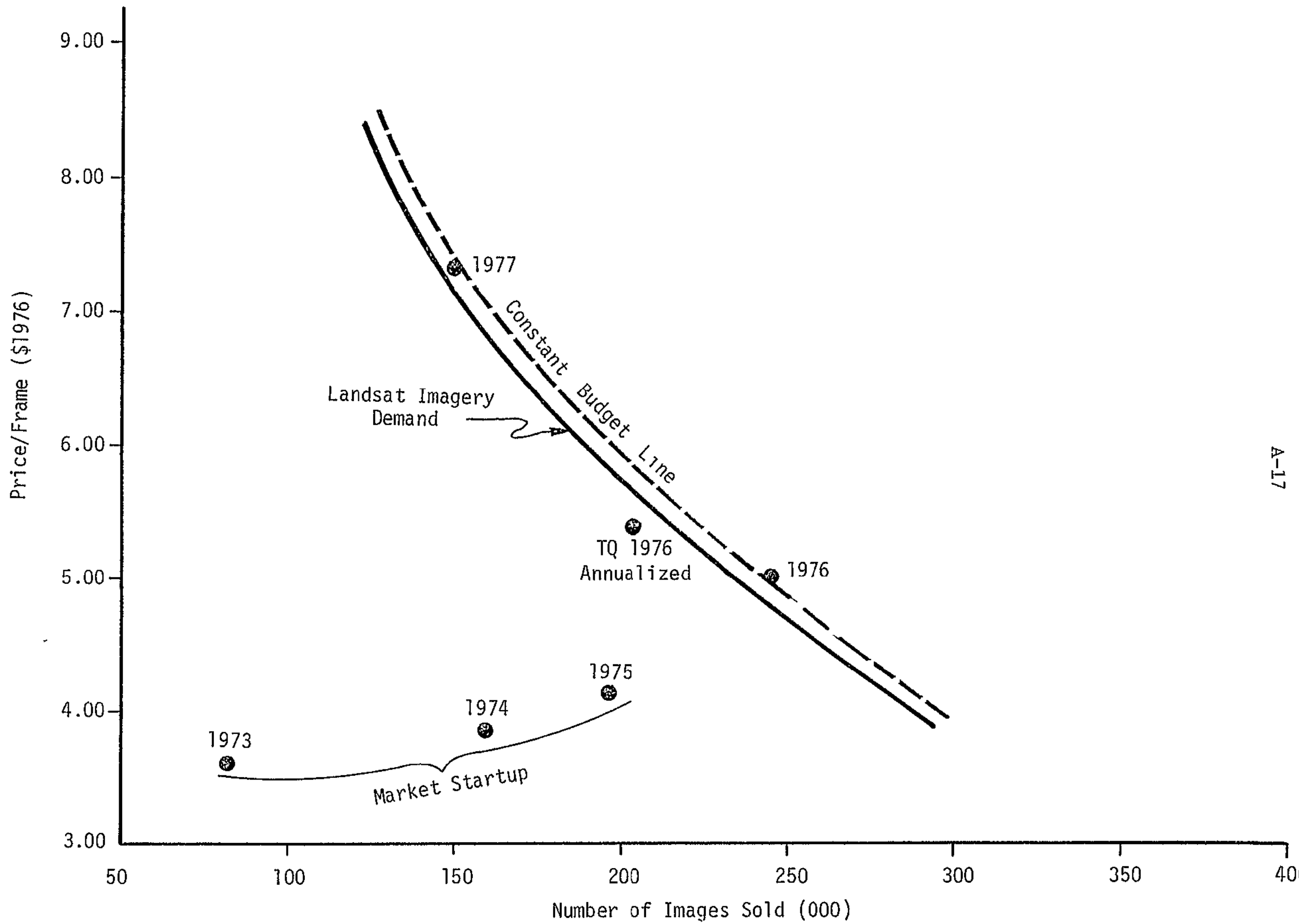

FIGURE A-1. HISTORICAL DEMAND VERSUS PRICE, LANDSAT IMAGERY, EROS DATA CENTER

55

available (better resolution, spectral quality, enhancements, and so on), the curve will shift upward to reflect the increased value of such products.

The extent to which the data from 1976 on represent an elasticity phenomenon is dependent on several factors requiring further study. It is possible, for example, that the price-volume relationship indicated in Figure A-1 is not causal in nature. Volume may, as an example, have fallen since 1976 solely as a result of market saturation for imagery, as in the case of geologists already having purchased required data on major areas of interest before 1976. Concurrent with this, EROS Data Center has been adjusting prices to reflect costs, per OMB directives. The combination of events yields the relationship of Figure A-1, but does not represent an elasticity phenomenon. Current users may not have reacted to price, they simply may not have needed more data, regardless of price. An up to date survey of two or three principal markets for Landsat data would be necessary to provide further insight into existing relationships between price, volume, and product utility.

Price Sensitivity of Computer-Compatible Products

A discussion with a private geoexploration consultant showed the following relationship between cost elements in generating an enhanced image on a 100 x 100-mile scene from a computer-compatible Landsat tape (CCT):

$ 200	Landsat data tape	
100	Set-up charge for Landsat tape	
440	100 meter	Enhancement charge
550	80 meter	
880	50 meter	
1100	40 meter	
28	Color correction	
35/hundred	Tape record charges; 1900 required for 100 x 100-mile scene	
120	8" x 10"	Output charges
325	24" x 32"	

Discussions with major firms in the remote sensing service industry support these figures. Typical fees are $2200 for a 100 x 100-mile Landsat scene converted to an enhanced apparent 40-meter-resolution visual product.

Assuming a constant budget for enhanced product expenditures, users would purchase 50 percent less if the price of the enhanced image doubled. Since the Landsat data represents about 10 percent of the cost of generating enhanced products, the sensitivity to volume on the basis of computerized Landsat data cost can be represented as:

$$V = V_o \left(\frac{2200}{P^1} \right) ,$$

where

$$P^1 = (2000 + C) ,$$

or

$$V = V_o \left(\frac{2200}{C + 2000} \right) ,$$

where

V = the volume of enhancements sold (or demand for input CCT data) at price P1

P^1 = the price of the enhancement

V_o = the volume of enhancements sold at $2200 per image

C = the cost of a Landsat data tape, currently $200.

Illustrating the sensitivity of volume to input data tape cost,

$$\frac{V}{V_o} = \frac{2200}{2000 + C} .$$

If C were raised by a factor of 10, demand would decrease 45 percent. Tabulating this relationship yields:

Data Tape Cost	Demand V/V_o (Percent)
$ 0	110
200	100
500	88
1000	73
2000	55
2500	49

These results are treated parametrically in revenue projections below.

The data and relationships derived above are based on analysis of one Landsat data application, the generation of enhanced visual products from raw computer-compatible tapes. Further, the constant budget assumption of market behavior is limited, due to the scope of the current study. It is felt, however, that the relationships developed illustrate that the CCT is only one element of cost in generating the end product, and that similarly, most applications of computerized data will involve significant expenditures to obtain the desired product over and above the cost of the raw data. The end result is that computer-compatible product demand has much lower sensitivity to price than visual products. Further efforts should be directed toward identifying and analyzing specific computer-compatible products applications within several market areas to quantify the relationship between CCT cost and overall cost of data preparation and utilization. Relative benefits derived from the use of the information and the relative value of competing sources of information and complementary data inputs also require additional study.

Price Sensitivity for State Land Use Applications

In June of 1977, testimony was given by Joe D. Tanner, Commissioner of the Georgia Department of Natural Resources, to the Subcommittee on Space, Science and Applications of the House Committee on Science and Technology.

The subject of the testimony was Georgia's experience in the Landsat Technology Transfer Project with NASA. Two phases were involved.

(1) Phase I, completed in 1976, was to determine the feasibility of using satellite-derived land cover information for management applications, using NASA computers at no cost to the state

(2) Phase II, in progress, was to transfer the software and technology to Georgia and acquire the necessary capabilities and techniques.

Georgia, with 60,000 square miles, found that Landsat data provided a new capability in repetitive, accurate data which was valuable to statewide programs and planning. The Phase II effort was launched with the computer resources of the Georgia Institute of Technology, and involves the following Federal, state, and local agencies:

- Division of Natural Resources
  - Water Pollution Branch - non-point source pollution studies
  - Land Protection Branch - solid waste disposal site studies
  - Game and Fish Division
- USDA Soil Conservation Service - land cover trends
- U.S. Army Corps of Engineers - wetlands studies
- Office of Planning and Budget - land use studies
- Georgia Department of Natural Resources
  - Inventory of lakes and ponds
  - Distribution of mines and quarries
  - Fault and lineation studies
  - Sediment plumes
  - Other studies.

Both imagery and computer products have been utilized, by Georgia, in these applications. For purposes of the existing study, cost data on the computer products applications are the most significant part of the testimony.

Table A-6, taken from the testimony, presents four cases of Landsat computer tape data to produce maps. The two first cases cover 13,165-square-mile areas. The second two cases cover 5,000-square-mile areas. A mix of rectification, ground referencing, and classification schemes is utilized in the examples, with a resulting price-per-square-mile range of between \$.93 for a fully rectified and maximum likelihood map to \$.53 for an unrectified table-lookup map. The data cost (CCT from EROS Data Center) is \$.015 per square mile in the first two cases (13,165 square miles) and \$.04 per square mile in the last two cases. Tabulating the data cost of the four cases shown in Table A-6 yields:

TABLE A-6. SAMPLE CASES - STATE OF GEORGIA

(1) 1 SCENE	(A) Rectified	Setup	$ 700
		Training Sample Selection	1,984
	(B) Maximum Likelihood	Rectification	3,970
		Maximum Likelihood	5,290
	(C) Film Writer Output	1 Map	300
			$12,244
		or	$.93/Sq. Mile
(2) 1 SCENE	(A) Rectified	Setup	$ 700
		Training Sample Selection	1,984
	(B) Table Lookup	Table Lookup	3,970
	(C) Film Writer	1 Map	300
			$ 6,954
		or	$.53/Sq. Mile
(3) 5000 Sq. Miles			
	(A) Unrectified	Setup	$ 700
		Training Sample Selection	750
	(B) Maximum Likelihood	Maximum Likelihood	2,000
	(C) Color Coded	1 Map	200
	Printer/Plotter		$ 3,650
		or	$.73 Sq. Mile
(4) 5000 Sq. Miles			
	(A) Unrectified	Setup	$ 700
		Training Sample Selection	750
	(B) Table Lookup	Table Lookup	1,500
	(C) Color Coded	1 Map	200
	Printer/Plotter Map		$ 3,150
		or	$.63/Sq. Mile

Case	Total Cost (square mile)	Data Cost (square mile)	Data Cost/Total Cost (percent)
1	$.93	$.015	1.6
2	.53	.015	2.8
3	.73	.04	5.4
4	.63	.04	6.3

The results are consistent with the data on enhanced imagery, discussed above. Since a greater degree of computer time and also ground truthing is involved in the state land use applications, the input data are an even smaller cost of the end product. On this basis, the state land use planning demand for imagery should show from two to five times less sensitivity than other demand for computer-compatible products.

It is recommended that further study of state applications be made, with emphasis on data cost as a percent of overall cost in various application areas. Also, the degree to which budgetary constraints impact the amount of data purchased should be investigated. It is noted, for example, that the $200 for a computer tape may be highly visible as a line item in a state budget, while the other $10,000 in processing costs and ground truthing may be less visible.

Appendix A References

(A-1) Historical sales information, EROS Data Center, Sioux Falls, South Dakota, 1977.

(A-2) "A Cost-Benefit Evaluation of the Landsat Follow-On Operational System", Goddard Space Flight Center (March 1977), p 4-4, Table 4-1.

(A-3) Cotter, Charles H., The Physical Geography of the Oceans, American Elsevier Publishing Company, Inc., New York (1970), Chapter 1, p 25.

(A-4) Wukelic, G. E., Stephan, J. G., Smail, H. E., Landis, L., and Ebbert, T. F., "Survey of Users of Earth Resources Remote Sensing Data", Final Report from Battelle Columbus Laboratories to National Aeronautics and Space Administration, Office of Applications, Contract Number NASw-2800, Task 6 (March 31, 1976), pp 33-35.

(A-5) Goddard Space Flight Center, op. cit., pp 3-7.

(A-6) Martin, John H., Leonard, Warren H., and Stamp, David L., Principles of Field Crop Production, Third Edition, Macmillan Publishing Co., Inc., New York (1976), Chapter 1, p 21, Table 1-2.

(A-7) Ibid., Chapter 2, pp 37-39.

(A-8) "Earth Resources Survey Benefit-Cost Study, Appendix 5, An Analysis of Costs and Benefits from Use of ERS Data in State Land Use Planning", Earth Satellite Corporation and the Booze-Allen Applied Research Corporation for the U.S. Department of the Interior/Geological Survey (November 22, 1974), p 157.

(A-9) Ibid., p 54, Table II-2, p 149, Table IV-2.

(A-10) Ibid., p 114, Table III-9.

(A-11) Ibid., pp 113-123, Tables III-10, III-11, III-14, III-15.

(A-12) Brandenberger, A.J., "World Cartography: Study on the Status of World Cartography", Volume XIV, Department of Economic and Social Affairs, United Nations, New York (1976), p 86.

(A-13) Ibid., p 85, Table 10.

(A-14) "Report of the Federal Mapping Task Force on Mapping, Charting, Geodesy and Surveying", Executive Office of the President, Office of Management and Budget (July 1973), p 133.

(A-15) Brandenberger, A. J., op. cit., p 81, Table 4.

(A-16) Ibid., p 72.

(A-17) Ideal World Atlas, New Perspective Edition, Hammond Incorporated, Maplewood, New Jersey (1971), p 4.

(A-18) Executive Office of the President, Office of Management and Budget, op. cit., p 133.

(A-19) Ibid., p 2, Table 1.

(A-20) Ibid., p 138.

(A-21) Wukelic, G. E., op. cit., pp 36, 62, 85-87, 108-109, 119.

(A-22) Ibid., p 20.

APPENDIX B

COSTS FOR THE LANDSAT FOLLOW-ON OPERATIONAL SYSTEM

APPENDIX B

COSTS FOR THE LANDSAT FOLLOW-ON OPERATIONAL SYSTEM

Cost estimates for an operational Landsat system are provided in Tables B-1 and B-2; the data used were derived from information published by Goddard Space Flight Center and the General Accounting Office.[B-1,B-2]* These estimates are referenced to a follow-on system sized to process an average of 200 multispectral scanner (MSS) scenes and 100 thematic mapper (TM) scenes per day. The user subsystems are sized to produce the benefits determined in the GSFC study.[B-1]

Historical costs and a cost stream are shown in Table B-1, with costs for Landsats 1 and 2 grouped together under the years 1972 and 1975. Landsat C costs are indicated as all occurring in 1978. Subsequent spacecraft are assumed to be launched every three years. Under the assumption of an average life before refurbishment of every three years, an annual average cost is determined in the last column.

The annual average cost is recast into several categories and cumulated in Table B-2. These categories are equivalent to those usually discussed in outside user pricing policies of other Federal agencies when they provide goods or services for reimbursement.

There are some differences between the total costs quoted here and in the referenced publications. The differences between these estimates relate chiefly to differences in methodology rather than to differences in physical costs. The GSFC cost-benefit study is directed toward estimating initial and subsequent investments and operating expenses adequate to produce a benefit stream, and assumes only replacement of physically worn-out equipment. This study is directed toward examining the implications of many pricing policies.

These pricing policies will consider types of cost recovery from a variety of users, both in the Government and private sectors. In the range of potential policies, a maximum recovery policy might consider the recovery of all costs including the sunk costs in Landsats A, B, and C and interest thereon; a minimum recovery policy might consider the effects

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* References, denoted by superscript numbers, are at end of Appendix B.

TABLE B-1. LANDSAT COST STREAM - FUTURE PROGRAM IS BASED ON 100 TM AND 200 MSS FRAMES PER DAY, LANDSAT 1 AND 2 COSTS IN CURRENT YEAR DOLLARS, LATER LANDSAT COSTS IN CONSTANT 1976 DOLLARS IN MILLIONS

Research and Development or Capital Investment	Landsats 1 & 2 1972 & 1975	Landsat C[a] "1978"	Landsats D & E 1981	Augmentation Unit[a] 1984	Landsat F + Refurbishment 1987	Annual Ongoing Cost & Amort Stream
Refurbishment for Next S/C	--	--	--	--	14 0[f]	4 7
Spacecraft	↓	21.9	25 0	12 0	--	--
Payload		6.8	66.0	19.0	--	--
MS Scanner		6.5			34 5	11 5
Ground Operations		5.4	12[c]	4[c]	--	--
Reserve		1.7			--	--
Inst. Mgmt. System		0 4			--	--
	188 0	42 7				
Launch Vehicle Hardware[a,b]	9.0	5.0[d]	6 5[d]	6.5[d]	10.0[e]	3 3
Direct Launch Services[b]	4.0	2.0	2 0	2 0		
Operations Costs	58.0	21.0	70[c]	12 0[c]	--	--
Civil Service	--	--	3.3	2.7	2 7	0.9
Ongoing R&D in Support of Operational System[b]	--	--	--	--	15.0	5 0
Tracking and Data Acquisition/Ground Processing	incl ?	43.0	--	--	--	--
T&DA			6.0	4.5	4 5	1.5
Data Management			30.0	24 6	24 6	8.2
Civil Service			4.0	6.3	22.5	7.5
User Processing	--	--	--	--	--	--
Facilities or Facilities Depreciation	2.0	--	3.0	--	7 5	2 5
EROS Data Center	incl ?	13 0	48.0	48	48 0	16.0
Other Data Centers	incl ?	12.0	22 5	23.1	22 5	7.5
Totals	261 0	138 7	189.3	164.7	205 8	68 6
Average Annual Costs	43 5	46 2	99.4	54 9	68 6	68 6
			77.1 Avg			

Sunken Costs

12-yr amortization

(a) References Landsat's Role in an Earth Resources Information System, GAO, June 10, 1977, and A Cost-Benefit Evaluation of the Landsat Follow-On Operational System, GSFC, March 1977.
(b) BCL estimates of amounts needed to make a consistent, across-the-board cost estimate.
(c) Division of $82M and $16M "Mission Unique and Program Management" into amounts consistent with past activities
(d) Delta 3910 Hardware cost of $13M for two launches divided between two launch years
(e) GSFC estimate of STS costs for WTR; Telcon 18 August 77
(f) GSFC estimate of 30 percent refurbishment of $47M Landsat augmentation unit, $24M every three years for refurbishment plus transportation; Telcon 18 August 77.

TABLE B-2. CATEGORIZATION OF LANDSAT ANNUAL ONGOING COSTS AND AMORTIZATION* (CONSTANT 1976 DOLLARS IN MILLIONS)

COST CATEGORIES		ANNUAL COST	CUMULATIVE ANNUAL COST RECOVERY
	PUBLIC INTEREST		0
DIRECT USER COSTS	USER PROCESSING		
	DEPRECIATION OF EQUIPMENT	2.5	
	DATA CENTERS OPERATIONS COSTS	23.5	26.0
DIRECT ANNUAL AVERAGE COSTS	TRACKING AND DATA ACQUISITION PROCESSING		
	T&DA	1.5	
	DATA MANAGEMENT	8.2	
	CIVIL SERVICE	7.5	
	OPERATIONS COSTS - CIVIL SERVICE	0.9	
	SPACE TRANSPORTATION (1/2 STS/3 YRS)	3.3	
	REFURBISHMENT OF SPACECRAFT (30% OF INITIAL COST)	4.7	52.1
RECOVERY OF OPERATIONAL SYSTEM COSTS	ONGOING R&D IN SUPPORT OF OPERATIONS**	5.0	
	12 YEARS AMORTIZATION OF INITIAL INVESTMENT IN SPACECRAFT (LANDSAT D AND LATER)	11.5	68.6
RECOVERY OF ALL COSTS	INTEREST ON SUNK COST OF $400M @ 6%	23.9	
	20 YEAR AMORTIZATION OF SUNK COSTS (LANDSAT A, B, C)	20.0	112.5

* NASA/GSFC AND OMB INFORMATION (COST ASSUMED FIXED REGARDLESS OF VOLUME OR PRODUCT MIX)

** BCL ESTIMATE

of recovering only the costs of the physical media upon which the data are to be recorded. Thus, the estimate of a cost does not imply that the user charge policy ultimately selected will recover that estimated cost.

The major differences between the estimates of References (B-1) and B-2 and the costs derived here are:

- For the Delta launches of Landsats D and E, there does not appear to be a charge for direct launch services in addition to that for launch vehicle hardware. The direct launch services for a Delta 3910 from WTR are estimated at $2M. The STS charge of $10M appears to be adequate to cover these services if the Landsat requires 33 percent to 40 percent of the Shuttle bay.
- An ongoing R&D program is considered both desirable and necessary for the best use of the system. A level of effort of $5M per year is estimated to provide the technology, but not the hardware, for follow-on equipment and to assist in the optimum use of the existing equipment.
- The initial investment in the space segment is amortized over 12 years. While the equipment is very likely to have a much longer physical life, the three spacecraft having been refurbished only once, the technology represented by the equipment is very likely to be obsolescent after 9 or 12 years. This amortization period is selected on the basis of an estimate of technological obsolescence; other periods may be more appropriate and might be used.

Appendix B References

(B-1) "Landsat's Role in an Earth Resources Information System", Report by the Comptroller General to the Congress (June 10, 1977).

(B-2) "A Cost-Benefit Evaluation of the Landsat Follow-On Operational System", Goddard Space Flight Center (March 1977).

APPENDIX C

REVENUE RECOVERY ASPECTS OF POTENTIAL LANDSAT PRICING POLICIES

APPENDIX C

REVENUE RECOVERY ASPECTS OF POTENTIAL LANDSAT PRICING POLICIES

From the discussion in the main body of the report, it is apparent that the Landsat operational system has many characteristics of other Federal information services. A pricing policy similar to those of other Federal information systems is, therefore, strongly indicated for many of its activities. The substantial Federal use of the system also provides analogies to goods or services for which higher cost levels are recovered. This study has determined the approximate levels of charges when photographic products are included in sales projections and discusses the implications of several alternative policies. These policies are:

- A Federal information service policy under which only the average costs of dissemination and dissemination facilities would be recovered
- A public good/service policy where the good/service is used by both the Government and the public. The public would be charged the pro-rata share of current annual costs, as in the case of expendable launch vehicles. Recovery of annual operating costs and average annual system (including investment) costs are both considered
- A publicly owned commodity policy where the good/service is used for predominately non-public purposes. Both Government and non-Government users would be charged an equivalent to a commercial price in the manner of the Panama Canal, TVA electricity, and Government helium.

In all cases considered in this Appendix, it is assumed that photographic products essemtially similar to those currently available from EROS and other data centers will be available at a charge which recovers the direct costs of processing and distribution but which does not recover any significant amount of system costs. An average price of $15 is used for photographic products, and tape prices are calculated. For

an all-tape case, the prices are the same as those determined in Figure 5 in the main body of the text. The implications of selecting each of these policies are discussed in terms of the net cost recovery to the Government, the effect of implied price changes on future market demand, and other pertinent considerations such as different product mixes. The gross prices and potential deficit to the government have been calculated in Table C-1 for four recovery policies and three product mixes. Those price calsulations are parametric and are based on the assumption that the estimated potential demand will appear at or near current prices but demand will be reduced as prices are raised significantly. The product mixes are based on analysis of demand by sector as determined in Appendix A. The high photographic product mix is included to illustrate the difficulties of cost recovery with low unit prices on photo products. The average charge of $15 per photograph is used since it is likely that any significantly higher charge might result in creating an opportunity for a private firm to enter business and divide the market by copying from available libraries. Further, even if photographic product costs are doubled or tripled from the price of $15, cost recovery is not assisted significantly. The tape prices in Table C-1 indicate the price which must be charged to recover the specified level of costs if that volume of tapes is sold in addition to the specified volume of $15 photographs. The potential reduction in tape demand due to the assumed price sensitivity of demand is indicated. This reduction was calculated using the constant purchase plus processing budget price-volume curve of Figure 6, which is the lower bound on the shaded region. The resultant potential deficit is indicated in the final column.

The major conclusion drawn from these parametric calculations is that any significant level of actual cost recovery will be difficult if the product mix actually achieved has a high photographic content. In addition, cost recovery policies which attempt to recover a very high level of costs may also be self-defeating even if the demand for Landsat products appears predominantly as a demand for tapes. The parametric calculations indicate potential deficits of $20.5 million and $46.1 million for attempts to recover average annual operating system costs and total costs, respectively, even when the demand for 65,354 scenes appears as a demand for tapes.

TABLE C-1. LANDSAT PRICING POLICY OPTIONS ANALYSIS
Summary of Policy Implications for Cost Recovery
Based on a Demand for 65,354 Scenes Per Year

Cost Recovery Policy	Annual Cost To Be Recovered	Product Mix Projection	Nominal Tape Price (1)	Potential Demand Reduction (2)	Potential Deficit for Specified Policy ($, Millions) (3)
Direct User Facility Cost Recovery	$26.0 Million	65,354 Tapes	$397	0-10%	$2.6M
		100,700 Photos 26,625 Tapes	$919	25%	$6.1M
		221,416 Photos 10,000 Tapes	$2,268	50%	$11.3M
Current Average Cost Recovery (Federal Good/Service)					
a) Annual Direct	$52.1 Million	65,354 Tapes	$797	20%	$10.4M
		100,700 Photos 26,625 Tapes	$1,900	45%	$27.8M
		221,416 Photos 10,000 Tapes	$4,877	70%	$36.5M
b) Average Annual Operating System	$68.6 Million	65,354 Tapes	$1,049	30%	$20.5M
		100,700 Photos 26,625 Tapes	$2,519	50%	$33.5M
		221,416 Photos 10,000 Tapes	$6,527	75%	$51.7M
Total Cost Recovery	$112.5 Million	65,354 Tapes	$1,721	40%	$46.1M
		100,700 Photos 26,625 Tapes	$4,169	65%	$72.9M
		221,416 Photos 10,000 Tapes	$10,917	83%	$93.9M

(1) An average charge per photo of $15 is assumed for reasons explained in text
(2) Based on constant user budget for data plus direct processing. See Figure 6 and related material in main text.
(3) Deficit estimates are based on specified cost recovery policies.

The implications of these calculations and those of the previous section are discussed briefly for each of the four policies selected for examination. All of these policies can be modified to provide price differentials for classes of users to support any of the non-cost goals. One such modification, the $15 photograph, is explicitly included.

Direct User Cost Recovery

This policy has the greatest probability of achieving the goal of recovery. The prices indicated by the forecast of demand are relatively close to current prices being charged by the EROS Data Center. If the forecast of demand is met as a demand for tapes, the indicated price of approximately $400 per tape is unlikely to cause any significant change in demand, and any shortfall in recovery is expected to be on the order of 10 percent of user costs of $26 million. If the predominant demand were for photographic products, however, the deficit would very possibly rise to the order of 50 percent of the direct user costs. Unless photo product prices were highly inelastic, and there are no data to support this conjecture, this deficit could not be lowered significantly by raising photographic prices.

A policy recovering direct user charges is also supportive of most of the non-cost objectives on optimization criteria. Resources would be used to the greatest extent, and since user charges would still be significant there would be little idle curiosity use (wastage), as might happen if the charges were nominal. Benefits (tangible and intangible) would also be maximized.

Current Average Cost Recovery

If the demand for scenes appears predominantly as a demand for tapes, it is probable that a pricing policy to achieve recovery of annual direct costs, estimated at $52.1 million per year, would be marginally successful. Data tape prices in the range of $797 to $1136 are indicated, with demand estimated to drop approximately 20 percent from that forecast. At the lower price level of $797 the potential deficit is

estimated at $10.4 million, while at the higher price level, a hypothetical price-volume relationship indicates full recovery. At this price level, however, the data costs would be approximately 50 percent of current tape processing costs. Little direct and explicit information is available to indicate how non-Governmental demand would be affected by an increase in price of this magnitude, but unless high dollar value benefits have already been domonstrated, it is quite possible that demand would stagnate. Cost recovery, if the product mix were to develop with any significant demand for photographic products, is very unlikely. The indicated deficits are greater than 50 percent.

A current average cost recovery policy is accordingly supportive of efficiency in the use of resources and potentially of maximizing recovery if demand is relatively inelastic. The prices required, however, are sufficiently high that applications which might be sensitive to the prices charged for data would be discouraged and benefits from widespread applications of Landsat data may not be realized.

Average Annual Operating System Cost Recovery

Data tape charges of the order of $1000 to $1800 per scene are indicated if the demand for 65,354 scenes materializes as a demand for data tapes. The potential deficit at the low end of this price range would be approximately $20 million per year. If the product mix achieved has a significant photographic component, the deficits could range from $33 million to $52 million, even if tape charges were raised to a range of $2500 to $6500 per scene. Since current costs of processing data tapes run approximately $2000 per tape, and should trend lower in the future, it is very doubtful that a large market for tapes would develop. Accordingly, unless it becomes certain that a high volume of data tapes will be demanded, a pricing policy which attempts to recover average annual operating system costs is very unlikely to approach that goal and would, therefore, probably not support either the complimentary goal of loss minimization or intangible goals such as maximization of benefits.

Total Cost Recovery

Unless demand is much higher than indicated by analysis of major operational Landsat applications, or other profitable uses can be demonstrated prior to establishing a total cost recovery policy, it is unlikely that the policy goals could be achieved. If the forecast of demand were achieved as a demand for tapes alone, a charge of $1721 per tape would be required. This would be close to the total user costs for processing that tape, and demand is likely to be reduced by 40 percent or more, resulting in a potential deficit $46 million. If demand reduction is considered in establishing the tape price, the resultant price is $7193, or approximately 3.6 times the current cost of both purchasing and using tapes. If the demand achieved has a high photographic content, tape prices would have to rise even more and/or deficits in recovery will be even higher.

APPENDIX D

<u>REVENUE-EXPENSE ANALYSIS OF LANDSAT/EARTH RESOURCES DATA SALES</u>

APPENDIX D

REVENUE-EXPENSE ANALYSIS OF LANDSAT/EARTH RESOURCES DATA SALES

A revenue-expense analysis of Landsat/Earth resources data sales has been conducted under a variety of alternatives/assumptions to illuminate the business aspects of Earth resources data dissemination. This analysis indicates the circumstances under which a non-government firm would be interested in assuming the disseminating role. The results of the analysis were, in general, not encouraging, and indicate that the price charged for Landsat tapes will have to be doubled for a government-operated facility to break even and will have to be tripled to be attractive for a commercial operator in a non-government facility to serve as a dissemination center.

This revenue-expense analysis covers the period 1977-1992 and uses several assumptions about ultimate volume and growth to achieve that volume as well as other assumptions about revenues and costs. Specifically:

- The ultimate volume of sales will be 65,000 scenes per year. Because of uncertainties in how the data will be used in the applications considered, no distinction is drawn between scenes represented by data tapes and scenes represented by photographic products in forecasts of future demand for the data.
- The growth to that volume of 65,000 scenes per year will follow one of three "S" growth curves. Such curves are typical of the adaption of a new capability.
- Revenues are assumed to be at one of three levels, $200 per scene (tape), $400 per scene, or $600 per scene. The current charge is $200 per tape.
- The costs for the main government center (EROS Data Center, or EDC) were taken from the Goddard cost-benefit evaluation(C-1)* for future-year costs; current costs were provided by the EDC.(D-2)

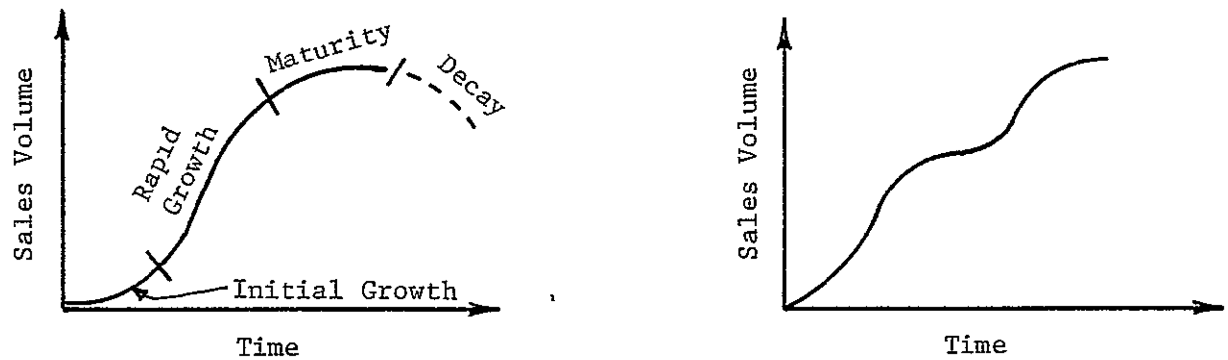
* References are at end of Appendix.

- The costs for a non-government data center have been estimated from the investment in the EROS Center.(D-2)
- All variations or cases studied in this assessment are assumed to be parametric; e.g., a change in the price charged for a tape or scene will have no significant effect on the number of tapes sold annually. Variations considered are believed to fall within the range where this assumption is valid.

Sales Growth

The ultimate volume of scenes demand for currently identified and future uses (65,000 scenes per year) has been used in other sections of this report and is derived in Appendix A. The growth paths from the current volume of approximately 2000 tapes (scenes) are projected by using a family of "S" curves. This curve, shown abstractly in Figure D-1(a), represents typical growth patterns for new products without appreciable subsequent innovations. This growth pattern is also typical of bacterial population growth, human population growth, etc. The population, sales, etc., start out at a very low level and exhibit a period of slow, steady growth, which is actually the beginning of an exponential growth curve. The population then continues on this exponential growth and for some period of time exhibits a very rapid increase. The growth then slows due to natural limits on that growth. In the case of population growth, these limits are usually geography or food supply or food supply technology. In the use of markets, growth is usually limited by competing products or saturation of the market at a price which approximates the supplier's cost and normal profit. The population or sales, etc., then exhibit a period of stability and are said to be mature, exhibiting a general population or volume level due to external factors. In the case of product sales, there tends to be a slight decline due to similar, competing products. When an entire industry or human populations are reviewed for growth, the growth pattern frequently appears to comprise

a series of S curves staggered upon one another. The population or industry sales grow within natural limits and then, usually through a technological innovation, enter another period of growth. This is illustrated in Figure D-1(b).



a. Single Growth Curve

b. Two Periods of Growth

FIGURE D-1. EXAMPLES OF "S" GROWTH CURVES (ABSTRACT)

Current Landsat data sales appear to be exhibiting maturity in that sales have been constant, and even declined somewhat in dollar volume. While this decline in volume is also associated with a price increase for photographic products, there has also been a slight decline in tape sales, for which there was no price increase. This decline is very likely associated with market saturation at current Landsat capabilities and prices of enhancing the data. The sales volume is unlikely to increase significantly until the improved resolution and other capabilities associated with Landsat D are available. Geophysical exploration is the major commercial application of Landsat data tapes at the present time and those firms using Landsat data tapes appear to have reached a steady state in their ability or desire to process and interpret the tapes at the present time. Only if a new or greatly expanded application arises are the sales likely to increase significantly in the near future.

Because the latest sales decline is not believed to be a significant fluctuation, the sales growth curves used in the revenue-cost analysis do not explicitly use the double growth curve of Figure D-1(b).

These growth curve assumptions, rather, are based on three different adaption periods or times to a mature or steady-state level of sales. As shown in Figure D-2, three different growth curves are estimated on the basis of growth to an annual volume of 65,000 scenes (tapes) per year over periods of 10, 15 and 20 years from 1972. Historical sales for the years 1973-1977 are indicated as the lower left tail of this family of curves. Thus, optimistic, expected and pessimistic cases are provided. Preliminary sales estimates for FY 1977 indicate that the optimistic case (growth to 65,354 scenes per year by 1982) is unlikely to be met. The preliminary estimate of $1.015 million in FY 1977 Landsat data sales is, however, consistent with either the expected or pessimistic growth assumptions of growth to 65,354 scenes per year in 15 or 20 years. With the introduction of Landsat D, in the next few years, data sales growth is expected to resume and it is considered most likely that growth will reach maturity by approximately 1987 rather than 1992 as shown in the pessimistic case. All sales are expressed as scenes equivalent to current data tapes; prices used later are based on current tape prices and no attempt is made to estimate the division between tape and photographic products. At the present time, an unenhanced color Landsat photograph is sold for approximately $15 while tape copies are sold for $200. Accordingly, the demand for photos is much greater than for tapes, but much of that demand is for decorative or educational uses as opposed to applications with a more direct use (e.g., geological exploration). These cultural or educational uses of photos are currently exhibiting much greater price sensitivity than would be expected of applications with direct economic payoffs. The price sensitivity in the photo sales is sufficiently great that demand has dropped by about one-third as the price charged has gone from approximately $8 to $15 for a color photo. If the earlier demand for photos had veen expressed as a demand for tapes, tape volume would already be at approximately 65,000 tapes per year.

None of these sales volume growth assumptions is directly related to the benefit stream growth curves of the Goddard cost-benefit study[D-1]. That study assumes that applications will be ready for use of data either as soon as the data are available or very shortly afterward and that the learning processes associated with the data use will be very rapid.

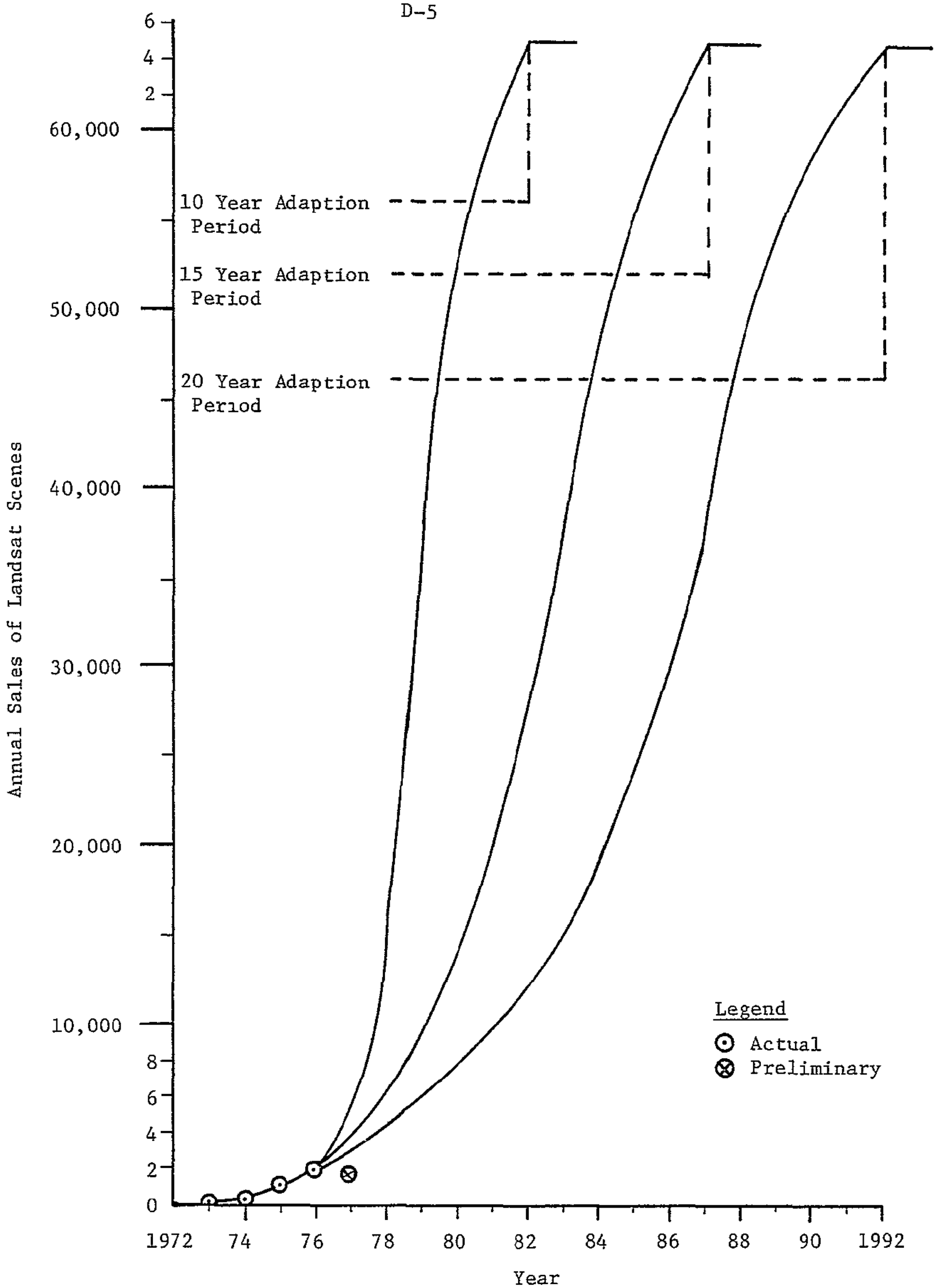


FIGURE D-2. ALTERNATIVE LANDSAT DATA SALES GROWTH PROJECTIONS

This study assumes, under the expected and pessimistic cases, that there will be delays in developing the applications and in transferring ability to use the data to those who will be processing and interpreting the data. The optimistic case, however, is consistent with the benefit curve of the Goddard study. The growth periods of 15 to 20 years are also typical of technology transfer times in other areas of scientific and technical endeavors.(D-3)

Tape/Scene Prices

This analysis is parametric; no change in sales volume is considered for tape/scene charges of $200, $400 or $600. Indeed, there are also reasons to believe that sales will be relatively insensitive to charges at this level. The current charge is $200 per scene; as will be shown later, this will not even recover the costs of operating the data dissemination center. From knowledge of the costs to the user of using the Landsat data, it is considered likely that doubling the charge per tape or scene to $400 is unlikely to affect long-term demand, and this level of charges permits recovery of costs under the current forecasts of the data center operations. The charge of $600 per scene (tape) is considered to be an upper limit of the charge which can be made without a severe impact on long-term demand for Landsat data. Because the nature of the market's sensitivity to price change is not well known, it is not considered feasible to model the probable increase in sales volume prior to a price increase followed by a drop immediately afterward. If a price increase is instituted at the time Landsat D tapes are made available, and applies only to the new tapes, however, there may be no discernible drop in volume.

Revenue Projections

The projected volume growth and prices are combined to yield nine alternating revenue streams for Landsat data sales. The revenue streams are presented in Table D-1 for the volume of tape/scene sales per year and prices of $200, $400 and $600 per tape/scene. The revenue streams

TABLE D-1. REVENUE PROJECTIONS FOR LANDSAT DATA SALES

Year	Sales of Scenes	Revenue ($, M) @ $200/Scene	Revenue ($, M) @ $400/Scene	Revenue ($, M) @ $600/Scene
		(a) 10-Year Adaption		
1977*	2,000*	1.0*	1.0*	1.0*
1978	16,000	3.2	6.4	9.6
1979	38,000	7.6	15.2	22.8
1980	52,000	10.4	20.8	31.2
1981	59,000	11.8	23.6	35.4
1982	65,000	13.0	26.0	39.0
1983	65,000	13.0	26.0	39.0
1984	65,000	13.0	26.0	39.0
1985	65,000	13.0	26.0	39.0
1986	65,000	13.0	26.0	39.0
1987	65,000	13.0	26.0	39.0
1988	65,000	13.0	26.0	39.0
1989	65,000	13.0	26.0	39.0
1990	65,000	13.0	26.0	39.0
1991	65,000	13.0	26.0	39.0
1992	65,000	13.0	26.0	39.0
16 Year Totals		$177.0	$353.0	$529.0
		(b) 15-Year Adaption		
1977*	2,000*	1.0*	1.0*	1.0*
1978	6,000	1.2	2.4	3.6
1979	10,000	2.0	4.0	6.0
1980	14,000	2.8	5.6	8.4
1981	20,000	4.0	8.0	12.0
1982	28,000	5.6	11.2	16.8
1983	38,000	7.6	15.2	22.8
1984	49,000	9.8	19.6	29.4
1985	56,000	11.2	22.4	33.6
1986	61,000	12.2	24.4	26.6
1987	65,000	13.0	26.0	39.0
1988	65,000	13.0	26.0	39.0
1989	65,000	13.0	26.0	39.0
1990	65,000	13.0	26.0	39.0
1991	65,000	13.0	26.0	39.0
1992	65,000	13.0	26.0	39.0
16 Year Totals		$135.4	$269.8	$404.2
		(c) 20-Year Adaption		
1977*	2,000*	1.0*	1.0*	1.0*
1978	5,000	1.0	2.0	3.0
1979	6,000	1.2	2.4	3.6
1980	8,000	1.6	3.2	4.8
1981	9,000	1.8	3.6	5.4
1982	12,000	2.4	4.8	7.2
1983	15,000	3.0	6.0	9.0
1984	19,000	3.8	7.6	11.4
1985	24,000	4.8	9.6	14.4
1986	30,000	6.0	12.0	18.0
1987	39,000	7.8	15.6	23.4
1988	48,000	9.6	19.2	28.8
1989	54,000	10.8	21.6	32.4
1990	58,000	11.6	23.2	34.8
1991	62,000	12.4	24.8	37.2
1992	65,000	13.0	26.0	39.0
16 Year Totals		$91.8	$182.6	$273.4

* Volume and revenue for 1977 represent preliminary estimates of results.

provided are considered to represent the extreme range of potential future revenues under the assumption that Landsat data are adapted for uses outlined in the benefit-cost study(D-1) in time spans typical of technological transfer in other areas.(D-3)

Costs and Other Revenue

Costs and other non-Landsat revenues for the data center have come from two sources. Current costs and revenue experience were provided by EDC in a telephone conversation(D-2). Costs for the expanded capabilities required to support the Landsat follow-on program were taken from the Goddard cost-benefit study(D-1). The current and forecast expenses and non-Landsat revenues are presented in Table D-2. The current EDC budget for operating expenses is approximately $12 million per year, $8 million of which is covered by an appropriation while the remaining $4 million comes from other sources. Among these other sources is $2.6 million in product sales of all types (54 to 65 percent Landsat products), $400,000 in reimbursement for training activities, and a $1 million transfer payment from the appropriation for the National Cartographic Information Center (NCIC). This transfer payment compensates the EDC for maintaining their image records in such a manner that the NCIC can locate either an aircraft or Landsat image of a scene by geographic coordinates so that the images can be used by the NCIC rapidly. At the present time the EDC maintains an archive of approximately 5 million aircraft images in comparison with approximately 1 million Landsat images.(D-2)

Future costs for EDC are estimated to be $16 million in operations expenses starting in 1981. In addition, a capital expenditure of $13 million over 1978-1980 will be required for computers and other processing equipment.(D-1) The transition between the current Landsat system and the follow-on system is estimated by an annual increase of $1 million per year in operations during the capital procurement phase from 1978 to 1980.

Costs of the data centers (e.g., for agriculture) are not included in this analysis as they are considered to reflect the cost of applying the data rather than disseminating the data. The costs of the NASA data

TABLE D-2. LANDSAT/EROS DATA CENTER COSTS AND MISCELLANEOUS REVENUE

Year	Costs, $ in millions		Revenues from Other Activities, $ in millions		
	Operations[(a)]	Capital[(b)]	Aircraft Images	Training Activities	NCIC[(c)]
1977	12.0*	–	0.381*	0.400*	1.0*
1978	13.0†	1.0	0.8		1.0
1979	14.0†	6.0	0.8		1.0
1980	15.0†	6.0	0.8		1.0
1981	16.0	–	0.8		1.0
1982	16.0	–	0.8		1.0
1983	16.0	–	0.8		1.0
1984	16.0	–	0.8		1.0
1985	16.0	–	0.8		1.0
1986	16.0	–	0.8		1.0
1987	16.0	–	0.8		1.0
1988	16.0	–	0.8		1.0
1989	16.0	–	0.8		1.0
1990	16.0	5.0	0.8		1.0
1991	16.0	4.2	0.8		1.0
1992	16.0	–	0.8		1.0
16 Year Total	$246.0	$22.2	$12.8		$16.0

(a) 1977 represents current costs (Reference D-2); † represents transition costs; follow-on costs are taken from Reference D-1.
(b) As taken from Reference D-1.
(c) NCIC = National Cartographic Information Center.
* Preliminary estimate of 1977 costs and revenues.
† Estimated transition requirements.

management system are similarly considered to be part of the space-to-ground link and also not included in this analysis.

Costs for a Potential Commercial Operator

This analysis also considers the potential that a non-government or commercial operator may provide the data dissemination service function Three alternative methods of commercial operation are considered: a contractor would operate the existing EROS Data Center using government-

furnished equipment (GOCO), or the contractor would provide a turnkey operation using contractor-furnished facilities and equipment, or the operator would be given the EROS Center as an incentive to operate.

In the case of a GOCO operator, it is considered that the current estimates of the EROS Data Center would be very close to those of the GOCO operator. The current mode of operation uses only 55 to 60 civil servants with total employment of about 350[D-2]. While the operator might be able to achieve some economies through a different mix of labor than is currently being used by the EDC, the operator will see additional costs not experienced by the government in tbe budget for the center. Among these costs are the employer's contribution to the Social Security Syatem (~ 6 percent) and other payroll taxes such as workmen's and unemployment compensation. In addition to payroll levies, the employer would very likely also have a benefits package including employer contributions to retirement and medical insurance funds. The contractor will also be receiving a fee over and above these costs. Thus, any economies of using a different labor or wage mix are expected to be offset by other costs as indicated.

In the alternative case of a commercial operator using its own facility, the costs are expected to be higher by the recovery of the operator's investment and profit on that investment. The investment in the EROS Data Center since 1973 approximates $20 million on a replacement basis. The main building cost $6 million and a smaller maintenance/facilities support building cost $500,000. The investment in laboratory equipment and computers was in the range of $10 million to $14 million. If the commercial operator is to take over the archive of approximately five million aircraft photos and one million Landsat photos currently on hand and add to this archive and provide equivalent facilities and access to the data, it is very likely that the operator will have a similar investment. The operator will expect to recover physical depreciation over a period of 5 to 10 years on the laboratory and computer equipment and 20 to 30 years on the buildings. In addition, the operator will have to pay property taxes and insurance. The operator will also expect a profit on the investment equivalent to the higher range of quality private debt securities. In this analysis, the cost of a non-government facility is modeled through amortization of the estimated $20 million investment required at 20 percent per year. The resultant

charge of $4 million per year includes an allowance for profit and taxes on that profit as well as physical depreciation over reasonable lifetimes of equipment (5 to 10 years). This amortization charge is, however, based on an assessment at a distance and does not reflect the item-by-item assessment that a commercial operator would make before bidding upon such a venture. The earliest time a private operator could reasonably be in operation in such a facility is 1981 or 1982. This implies a total cost of $44 million over the eleven years remaining in the time frame of the analysis (1972-92).

The third case for this analysis can be formed by considering the implications of turning over the EROS Center to a private operator as an incentive to operate the Center without government support other than payment for its data products at the standard rates. If the facilities are donated under the restriction that the data dissemination function must be performed over the life of the facility, the effect of the donation on the operator's income is to provide a depreciation charge which shelters income from taxation. In this situation, the private operator would be receiving buildings worth approximately $6.5 million with a useful physical life of approximately 20 years without major renovation and approximately $10 to $14 million worth of equipment with a maximum useful working life of approximately 10 years, and which may, in fact, have a shorter working life. New equipment for Landsat D will cost $13 million and also has a useful life of approximately 10 years. The operator, as a first approximation, would consider the facilities and equipment depreciation account to be a subsidy of approximately $2.8 million per year, based upon their life expectancy for income tax depreciation purposes. This amounts to a subsidy of $30.8 million over the 11 years, 1982-1992. Since the operator would still be experiencing the ongoing operations costs of $12 million (currently) to $16 million (forecast) and would have to make some further capital investments, any operator would have to be certain of the revenue projections before committing to accept the task. Since current revenues are likely to be at the level of $2.5 to $3.5 million at least until Landsat D products become available, it is unlikely that any commercial operator will undertake the data dissemination task without a guaranteed subsidy. Comsat Corporation appears to have been interested in this task and made two separate investigations of the business aspects of the

operation with the cooperation and assistance of the EROS Center.[(D-2)] Comsat appears uninterested in pursuing the matter further at the precent time.

Thus, for the three alternatives, the costs of operation by a commercial operator are assessed as:

- Government-Owned, Contractor-Operated (GOCO) current facility: same as government operated
- Privately owned and operated facility: cost increases $4.0 million per year
- Private operator of government-donated facility: subsidy equivalent to $2.8 million per year.

These costs or equivalent subsidies are approximate and are unlikely to represent sufficient assurance to a commercial operator to enter an agreement with the Government without additional guarantees as will be shown in the following section.

Revenue-Expense Analysis

The revenue-expense analysis is conducted with the data from Tables C-1 and C-2 and the estimates of private operator costs/subsidies of the previous section. The results of an undiscounted cash flow analysis are presented in Table C-3 for the cases involving a government-operated and/or GOCO facility. It is considered that government-operated and government-owned, contractor-operated (GOCO) facilities will be approximately the same.

This analysis strongly indicates that the operation of the dissemination center will not break even unless the charge per scene (tape) is increased from the current level of $200 to at least $400 and the adaption of Landsat data occurs relatively rapidly. If the price remains at $200 per tape or scene or the adaption period is much greater than 15 years, the dissemination center is unlikely to be able to cover the projected level of costs.

Current market data indicate that Landsat adaption is unlikely to follow the 10-year adaption period. It will not be possible to decide whether the 15- or 20-year adaption period forecast is being followed until 1 or 2 years of Landsat D operational results are available. From investigation of the total costs of processing and interpreting data

tapes, it appears that the current price of the tapes ($200) is 10 to 20 percent of the current cost of processing and using the tapes ($1000-$2000). Thus, while some customers may be lost by raising the tape price to $400 to $600, demand is unlikely to be reduced significantly in the long run.

TABLE C-3. CASH-FLOW RESULTS FOR A GOVERNMENT OPERATED OR GOVERNMENT-OWNED, CONTRACTOR-OPERATED LANDSAT DATA DISSEMINATION FACILITY OVER THE PERIOD 1977-1992

	Millions of dollars, except for tape/scene prices				
Price Per Scene or Tape	Total Landsat Revenues	Total Other Revenues	Total Expenses	Net Revenue	Breakeven Year
		10-Year Adaption			
$200	117.0	28.8	268.2	-62.4	-
$400	353.0	28.8	268.2	+113.6	1981
$600	529.0	28.8	268.2	+289.6	1982
		15-Year Adaption			
$200	135.4	28.8	268.2	-104.0	-
$400	369.8	28.8	268.2	+30.4	1983
$600	404.2	28.8	268.2	+164.8	1982
		20-Year Adaption			
$200	91.8	28.8	268.2	-147.6	-
$400	182.6	28.8	268.2	-56.8	-
$600	273.4	28.8	268.2	+34.0	1986

tape price to $400 to $600, demand is unlikely to be reduced significantly in the long run.

The net revenue computations for both government and private operators are summarized in Table D-4, using the additional costs or implicit subsidies estimated for a commercial operator in the previous section.

The influence of the demand realized and the price per scene overwhelms considerations of additional costs or subsidies for privately purchased or donated facilities. There are only two cases where the

TABLE D-4. CASH FLOW RESULTS FOR A LANDSAT DATA DISSEMINATION CENTER UNDER A VARIETY OF OWNERSHIP ASSUMPTIONS FOR 1977-1992

	Millions of Dollars				
Price Per Scene or Tape	Net Revenue, Gov't. or GOCO Facility	Cost for Private Facility	Net Revenue, Private Facility	Implicit Subsidy for Donated Facility	Net Revenue, Donated Facility
			10-Year Adaption		
$200	-62.4	-44.0	-106.4	+30.8	-31.6
$400	+113.6	-44.0	+69.6	+30.8	+114.4
$600	+289.6	-44.0	+245.6	+30.8	+320.4
			15-Year Adaption		
$200	-104.0	-44.0	-148.0	+30.8	-73.2
$400	+30.4	-44.0	-13.6*	+30.8	+17.2
$600	+164.8	-44.0	+120.8	+30.8	+195.6
			20-Year Adaption		
$200	-147.6	-44.0	-191.6	+30.8	-116.8
$400	-56.8	-44.0	-100.8	+30.8	-26.0
$600	+34.0	-44.0	-10.0*	+30.8	+64.8

* The only cases examined where the cash flow changes significantly.

spectrum of forecast cash flows changes from positive to negative, as is indicated by an asterisk in the table.

Thus, the ability to achieve a positive cash flow (become profitable in private-sector terms) is approximately independent of the mode of operating the data dissemination facility. The major problem in achieving a positive cash flow during the period examined is the level of sales volume and prices received. The volume is not expected to increase dramatically until Landsat D data are available, and unless Landsat D data are significantly more widely used than previous imagery, the costs of operating any center will exceed revenues at unit prices which will not severely impact sales volume. Unless a commercial operator is satisfied that sales will lead to a profitable business, the operator will require a subsidy or guarantee to undertake the dissemination role.

The estimated levels of annual subsidies required to break even under the assumption of a 15-year adaption period are presented in Table D-5. They are calculated as 5-year averages and as an average over the period from 1978 to 1992. Positive cash flows or returns are indicated by parentheses.

TABLE D-5. ESTIMATES OF THE RANGE OF ANNUAL SUBSIDIES REQUIRED FOR THE DATA DISSEMINATION CENTER DURING 1978-1992 IF LANDSAT DATA ACHIEVE ADAPTION WITHIN 15 YEARS

	Millions of Dollars			
Price Per Scene or Tape	Average Subsidy 1978-1982	Average Subsidy 1983-1987	Average Subsidy 1988-1992	Average Subsidy 1978-1992
	Government Operation or GOCO Operation			
$200	12.5	3.4	3.0	6.3
$400	9.3	(7.3)*	(10.0)	(2.6)
$600	6.2	(18.0)	(23.0)	(11.6)
	Private Operator in Private Facility			
$200	16.5	7.4	7.0	9.3
$400	13.3	(3.3)	(6.0)	0.9
$600	10.2	(14.0)	(19.0)	(8.0)

* Parentheses indicate a net recovery; no subsidy is needed.

The subsidies required are substantial in the first 5 years of any but the most optimistic scenarios. For the expected demand forecast and a reasonable unit price (e.g., \$400 to \$600), however, a subsidy is not required after the first 5 years since there is expected to be a net recovery.

The case of a commercial operator in the donated EROS facility has not been displayed in Table D-5 because the benefit of owning the facility, and thus being able to claim depreciation against revenues, is of value to the commercial operator only if the net revenue is positive. An operator is very likely to require a subsidy in the early part of the program which would be equivalent to that required of the government operation and the effect of the donated facility would be realized only after the revenue picture improves.

Conclusions of the Revenue-Expense Analysis

Unless demand for data greatly exceeds current forecasts, data charges will have to be raised from the current level of \$200 per scene to at least \$400 to provide cost recovery for the dissemination center.

If data demand is not adversely affected by this modest increase in charges, it is reasonable to expect the data dissemination center to break even in the long run and not require a high level of subsidy beyond the first few years.

Commercially owned or contractor-operated dissemination facilities appear feasible if an initial subsidy is provided. The major problem lies in convincing potential operators that the business volume will appear. To date, this volume is more than an order of magnitude below that needed to sustain a commercially operated facility on a self-supporting basis.

References

(D-1) "A Cost-Benefit Evaluation of the Landsat Follow-On Operational System", Goddard Space Flight Center, Greenbelt, Maryland, March 1977.

(D-2) Telephone Conversation between Gary Metz of the EROS Data Center, Sioux Falls, South Dakota, and R. W. Earhart, Battelle's Columbus Laboratories, November 1977.

(D-3) Battelle's Columbus Laboratories; "Science, Technology and Innovations", February 1973, Sponsored by NSF under Contract NSF-C667.

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